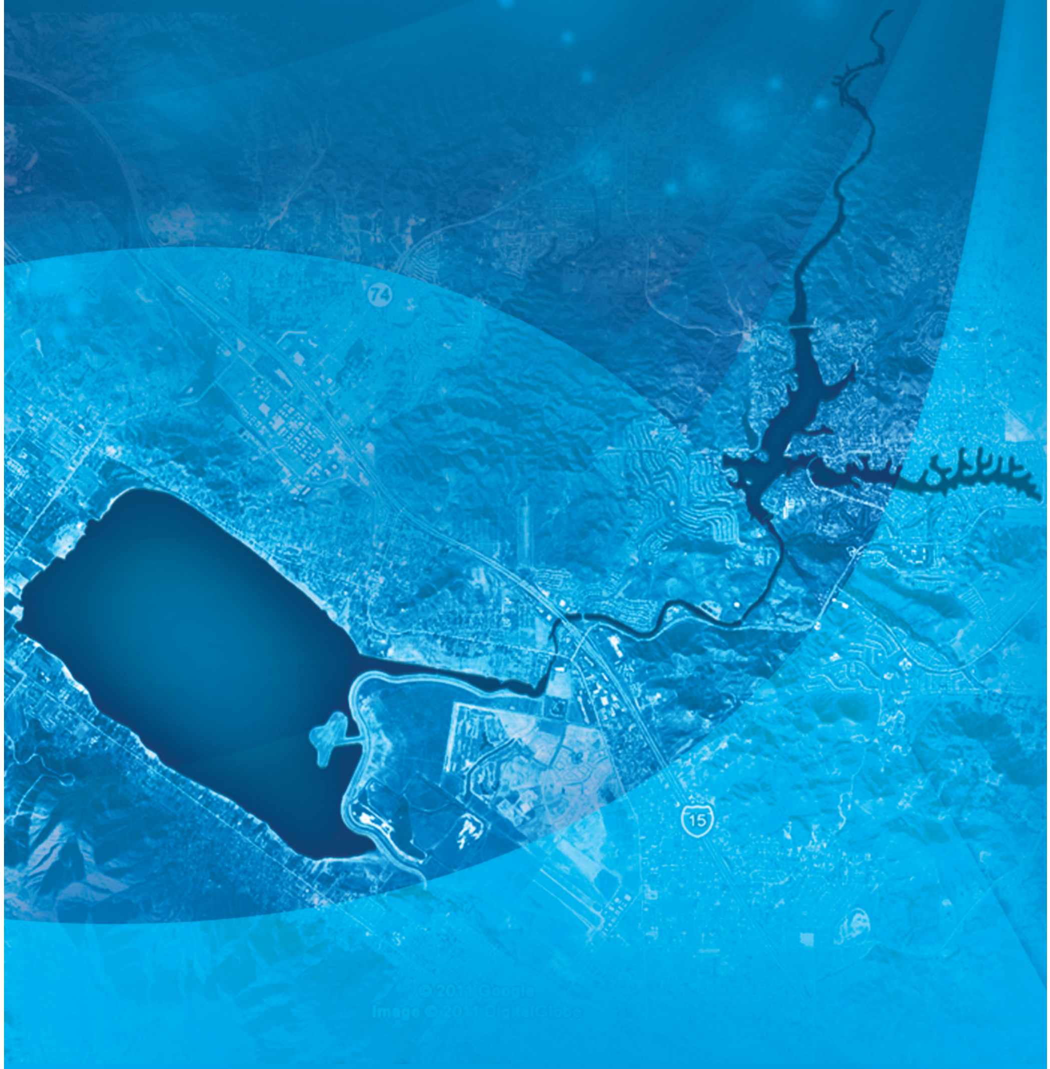
Comprehensive Nutrient Reduction Plan for Lake Elsinore and Canyon Lake

January 28, 2013



Riverside County
Flood Control & Water
Conservation District on
behalf of:

County of Riverside and
the Cities of Beaumont,
Canyon Lake, Hemet,
Lake Elsinore, Menifee,
Moreno Valley, Murrieta,
Perris, Riverside,
San Jacinto, and Wildomar

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List of Acronyms

Al	Aluminum
BMPs	Best Management Practices
CAFO	Concentrated Animal Feeding Operations
CAP	Compliance Assistance Program
CEQA	California Environmental Quality Act
cfs	cubic feet per second
CL	Canyon Lake
CNRP	Comprehensive Nutrient Reduction Plan
CWA	Clean Water Act
CWP	Center for Watershed Protection
DAMP	Drainage Area Management Plan
EPA	Environmental Protection Agency
LE	Lake Elsinore
LID	Low Impact Development
mL	Milliliters
MS4	Municipal Separate Storm Sewer System
NPDES	National Pollutant Discharge Elimination System
PTP	Pollutant Trading Plan
RCFC&WCD	Riverside County Flood Control and Water Conservation District
ROWD	Report of Waste Discharge
RWQCB	Regional Water Quality Control Board
SAWPA	Santa Ana Watershed Protection Authority
SCAG	Southern California Association of Governments
SJR	San Jacinto River
TMDL	Total Maximum Daily Load
USGS	United States Geological Study
WQMP	Water Quality Management Plan
WQO	Water Quality Objective

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Section 1
Background and Purpose

The Santa Ana Regional Water Quality Control Board ("Regional Board") adopted a Municipal Separate Storm Sewer System (MS4) permit for Riverside County on January 29, 2010 that requires the development of a Comprehensive Nutrient Reduction Plan (CNRP). The CNRP is a long term plan designed to achieve compliance with wasteload allocations (WLAs)[1] established in the Lake Elsinore and Canyon Lake Nutrient Total Maximum Daily Loads ("Nutrient TMDLs"). This document fulfills this MS4 permit requirement. The following sections provide the regulatory background, purpose, and framework of the CNRP.

1.1 Regulatory Background

The 1972 Federal Water Pollution Control Act and its amendments comprise what is commonly known as the Clean Water Act (CWA). The CWA provides the basis for the protection of all inland surface waters, estuaries, and coastal waters. The federal Environmental Protection Agency (EPA) is responsible for ensuring the implementation of the CWA and its governing regulations (primarily Title 40 of the Code of Federal Regulations) at the state level.

California's Porter-Cologne Water Quality Control Act of 1970 and its implementing regulations establish the Santa Ana Regional Board as the agency responsible for implementing CWA requirements in the Santa Ana River Watershed. These requirements include adoption of a Water Quality Control Plan ("Basin Plan") to protect inland freshwaters and estuaries. The Basin Plan identifies the beneficial uses for waterbodies in the Santa Ana River watershed, establishes the water quality objectives required to protect those uses, and provides an implementation plan to protect water quality in the region (RWQCB 1995, as amended).

The CWA requires the Regional Board to routinely monitor and assess water quality in the Santa Ana River watershed. If this assessment indicates that beneficial uses are not met in a particular waterbody, then the waterbody is found to be impaired and placed on the state's impaired waters list (or 303(d) list2). This list is subject to EPA approval; the most recent EPA-approved 303(d) list for California is the 2010 list3.

Waterbodies on the 303(d) list require development of a Total Maximum Daily Load (TMDL). A TMDL establishes the maximum amount of a pollutant that a waterbody can receive (from both point and nonpoint sources) and still meet water quality objectives.

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[1] As set forth in Tables 9 and 10 in the MS4 permit (Order No. R8-2010-0033), the CNRP is addressing both urban WLAs and loads from septic systems.

[2] 303(d) is a reference to the CWA section that requires the development of an impaired waters list.

[3] On November 12, 2010, EPA approved California's 2008-2010 Section 303(d) list of impaired waters and disapproved the omission of several water bodies and associated pollutants that meet federal listing requirements. EPA identified additional water bodies and pollutants for inclusion on the State's 303(d) list. On October 11, 2011, EPA issued its final decision regarding the waters EPA added to the State's 303(d) list.

1.2 Lake Elsinore and Canyon Lake Nutrient TMDLs

Through its bi-annual water quality assessment process, the Regional Board determined that Lake Elsinore was not attaining its water quality standards due to excessive nitrogen and phosphorus. This finding led to the Regional Board placing Lake Elsinore on the 303(d) list in 1994 as a result of the impairment of the following uses: warm water aquatic habitat (WARM), and water contact and non-water contact recreation (REC1 and REC2).

Similarly, a Regional Board water quality assessment of Canyon Lake identified excessive nutrients causing impairment of the lake. Accordingly, Canyon Lake was listed on the 303(d) list in 1998. The following uses were identified as impaired by nutrients: municipal water supply (MUN), warm water aquatic habitat (WARM), and water contact and non-water contact recreation (REC1 and REC2).

Regional Board staff prepared the Lake Elsinore Nutrient TMDL Problem Statement and the Canyon Lake Nutrient TMDL Problem Statement in October 2000 and October 2001, respectively. These reports documented the impairment caused by excessive nutrients and provided preliminary recommendations for numeric targets to ensure beneficial uses of both lakes would be protected.

Following completion of the Lake Elsinore and Canyon Lake Problem Statements, a number of studies were conducted:

- UC Riverside conducted studies to quantify the internal nutrient loading from Lake Elsinore and Canyon Lake sediments, as well as the response of the lakes to these internal nutrient loadings.
- Regional Board staff and watershed stakeholders conducted in-lake monitoring to evaluate the current nutrient cycling processes and to determine the in-lake response to nutrient loads from the watershed and characterize spatial and temporal trends of nutrients, algal biomass, dissolved oxygen, and other water quality parameters.
- Regional Board staff and watershed stakeholders implemented a watershed-wide monitoring program that assessed nutrient loadings from various land uses in the watershed.
- Lake Elsinore San Jacinto Watershed Authority (LESJWA), a joint powers authority, implemented watershed modeling to simulate nutrient loads under different hydrologic conditions and assess the impact of various implementation plans on the water quality of each lake.
- LESJWA conducted a survey of lake users from April through September 2002 to link lake users' opinions of Lake Elsinore to water quality parameters monitored on the same day as surveys were conducted.

The Regional Board used the data developed from the above studies to develop the Nutrient TMDLs. This information was reported in the Regional Board's Staff Report, released for public review May 21, 2004. The purpose of the Staff Report was to provide the technical basis for the proposed TMDLs. Table 1-1 summarizes the nutrient numeric targets applicable to Lake Elsinore and Canyon Lake.

Public workshops were held on June 4, and September 17, 2004 to gather public comment on the proposed Nutrient TMDLs. Based on the comments received, the Regional Board prepared final Nutrient TMDLs that were adopted on December 20, 2004 (Order No. R8-2005-0037). The subsequent TMDL approval process included: State Water Resources Control Board (State Board) approval on May 19, 2005, Office of Administrative Law approval on July 26, 2005, and EPA approval on September 30, 2005.

Table 1-1. TMDL Compliance Requirements

Indicator	Lake Elsinore	Canyon Lake
Total Phosphorus Concentration (Final)	Annual average no greater than 0.1 mg/L to be attained no later than 2020	Annual average no greater than 0.1 mg/L to be attained no later than 2020
Total Nitrogen Concentration (Final)	Annual average no greater than 0.75 mg/L to be attained no later than 2020	Annual average no greater than 0.75 mg/L to be attained no later than 2020
Ammonia Nitrogen Concentration (Final)	Calculated concentrations to be attained no later than 2020 Acute: 1 hour average concentration of total ammonia nitrogen (mg/L) not to exceed, more than once every three years on the average, the Criterion Maximum Concentration (CMC) (acute criteria), where $CMC = 0.411/(1+10^{7.204-pH}) + 58.4/(1+10^{pH-7.204})$ Chronic: 30-day average concentration of total ammonia nitrogen (mg/L) not to exceed, more than once every three years on the average, the Criterion Continuous Concentration (CCC) (chronic criteria), where $CCC = (0.0577/(1+10^{7.688-pH}) + 2.487/(1+10^{pH-7.688})) * \min (2.85, 1.45*10^{0.028(25-T)}$	Calculated concentrations to be attained no later than 2020 Acute: 1 hour average concentration of total ammonia nitrogen (mg/L) not to exceed, more than once every three years on the average, the Criterion Maximum Concentration (CMC) (acute criteria), where $CMC = 0.411/(1+10^{7.204-pH}) + 58.4/(1+10^{pH-7.204})$ Chronic: 30-day average concentration of total ammonia nitrogen (mg/L) not to exceed, more than once every three years on the average, the Criterion Continuous Concentration (CCC) (chronic criteria), where $CCC = (0.0577/(1+10^{7.688-pH}) + 2.487/(1+10^{pH-7.688})) * \min (2.85, 1.45*10^{0.028(25-T)}$
Chlorophyll a concentration (Interim)	Summer average no greater than 40 µg/L; to be attained no later than 2015	Annual average no greater than 40 µg/L; to be attained no later than 2015
Chlorophyll a Concentration (Final)	Summer average no greater than 25 µg/L; to be attained no later than 2020	Annual average no greater than 25 µg/L; to be attained no later than 2020
Dissolved Oxygen Concentration (Interim)	Depth average no less than 5 mg/L; to be attained no later than 2015	Minimum of 5 mg/L above thermocline; to be attained no later than 2015
Dissolved Oxygen Concentration (Final)	No less than 5 mg/L 1 meter above lake bottom to be attained no later than 2015	Daily average in hypolimnion no less than 5 mg/L; to be attained no later than 2015

TMDL coordination efforts have been underway since August 2000, well before adoption of the Nutrient TMDLs. These activities were coordinated and administered through the LESJWA. Following TMDL adoption, the existing TMDL stakeholders formally organized into a funded TMDL Task Force ("Task Force") in 2006. This Task Force in coordination with LESJWA has been actively involved in the implementation of the TMDL requirements, which include 14 tasks. Attachment A summarizes the status of the implementation of these tasks, in particular those that are relevant to the MS4 Permittees in Riverside County subject to the Nutrient TMDLs.

1.3 Riverside County MS4 Permit

In large metropolitan areas with interconnected MS4s, MS4 permits are often issued to multiple Permittees that work cooperatively to implement the requirements. This is the case for the Riverside County area where the MS4 facilities within the Santa Ana Region of Riverside County are permitted under a single area-wide MS4 permit. The Riverside County Flood Control and Water Conservation District (RCFC&WCD) is the Principal Permittee and the County of Riverside and the Cities of Beaumont, Calimesa, Canyon Lake, Corona, Eastvale, Hemet, Jurupa Valley, Lake Elsinore, Menifee, Moreno Valley, Murrieta, Norco, Perris, Riverside, San Jacinto, and Wildomar are the Co-Permittees.

The first MS4 permit was issued by the Regional Board to the MS4 Permittees in 1990. The 1990 MS4 permit was followed by MS4 permits issued in 1996, 2002 and 2010. The 2002 MS4 permit included a general requirement to update MS4 program documents, as appropriate, to support TMDL implementation requirements. As a result, the Permittees amended their Drainage Area Management Plan (DAMP) and Water Quality Management Plan (WQMP) on July 29, 2006 to incorporate Chapter 13 – TMDL Implementation. This Chapter included specific initial actions taken to address the Lake Elsinore/Canyon Lake Nutrient TMDLs (See Sections 13.1 – 13.4)

The Regional Board adopted a new MS4 permit for the Santa Ana Region of Riverside County on January 29, 2010 (Order No. 2010-0033, NPDES No. CAS618033). This permit is the first to incorporate requirements directly addressing the WLAs for Lake Elsinore and Canyon Lake. Specifically, this permit explicitly requires implementation of tasks contained within the TMDLs and compliance with the WLAs. The permit also requires preparation of a CNRP; which describes the specific actions that have been taken or will be taken to achieve compliance with the TMDL's WLA by December 31, 2020.

1.4 Comprehensive Nutrient Reduction Plan

This section provides information on the requirements for CNRP development and the applicability of the plan to urban discharges in the watershed that drains to Canyon Lake and Lake Elsinore. In addition, information is provided on the general framework of this plan and the process associated with its development.

1.4.1 Purpose and Requirements

The need for the development of the CNRP is described in the findings section of the MS4 permit, e.g.:

- *Section II.F.23* – Interim compliance (compliance determination prior to the final WLA compliance dates) determination with the WLAs in the TMDLs will be based on the Lake Elsinore and Canyon Lake (LE/CL) Permittees progress towards implementing the various TMDL Implementation Plan tasks as per the resultant studies and plans approved by the Regional Board. The LE/CL Permittees [MS4 Permittees] are required to develop a CNRP designed to achieve compliance with the WLAs by the final compliance date for approval of the Regional Board. In the absence of an approved CNRP, the WLAs specified in the approved Canyon Lake/Lake Elsinore Nutrient TMDL will constitute the final numeric WQBELs [Water Quality Based Effluent Limits].

- *Section II.K.4.b.v* – The Regional Board recognizes that additional research is needed to determine the most appropriate control mechanism to attain water quality standards for nutrients in these two lakes. This Order provides the LE/CL Permittees the flexibility to meet the WLAs through a variety of techniques. Even though the WLAs for the Canyon Lake and Lake Elsinore Nutrient TMDLs are expressed as WQBELs, if water quality standards in the Lakes are met through biological or other in-Lake control mechanisms, the LE]/CL Permittees' obligation to meet the WLAs is satisfied as the impairment for which the TMDLs were developed would not exist anymore. The Permittees in the affected watersheds are required to develop a CNRP designed to achieve the WLAs by the compliance dates specified in the TMDL. In the absence of an approved CNRP, the WLAs become the final numeric WQBELs for nutrients.

Based on these findings, the Regional Board established specific requirements for the CNRP's content. These requirements, found in Section VI.D.2.d in the MS4 permit, are intended to achieve compliance with TMDL WLAs as per the TMDL Implementation Plans. The LE/CL Permittees shall submit a CNRP by December 31, 2011, describing, in detail, the specific actions that have been taken or will be taken to achieve compliance with the urban WLA by December 31, 2020. The CNRP must include the following:

- Evaluation of the effectiveness of BMPs [Best Management Practices] and other control actions implemented. This evaluation shall include the following:
    - The specific ordinance(s) adopted or proposed for adoption to reduce the concentration of nutrients in urban sources.
    - The specific BMPs implemented to reduce the concentration of urban nutrient sources and the water quality improvements expected to result from these BMPs.
    - The specific inspection criteria used to identify and manage the urban sources most likely causing exceedences of water quality objectives for nutrients.
    - The specific regional treatment facilities and the locations where such facilities will be built to reduce the concentration of nutrient discharged from urban sources and the expected water quality improvements to result when the facilities are complete.
- Proposed method for evaluating progress towards compliance with the nutrient WLA for Urban Runoff. The progress evaluation shall include:
    - The scientific and technical documentation used to conclude that the CNRP, once fully implemented, is expected to achieve compliance with the urban waste load allocation for nutrient by December 31, 2020.
    - A detailed schedule for implementing the CNRP. The schedule must identify discrete milestones decision points and alternative analyses necessary to assess satisfactory progress toward meeting the urban waste load allocations for nutrient by December 31, 2020. The schedule must also indicate which agency or agencies are responsible for meeting each milestone.
    - The specific metric(s) that will be established to demonstrate the effectiveness of the CNRP and acceptable progress toward meeting the urban waste load allocations for nutrient by December 31, 2020.
    - The DAMP, WQMP and LIPs [Local Implementation Plans] shall be revised consistent with the CNRP no more than 180 days after the CNRP is approved by the Regional Board.
    - Detailed description of any additional BMPs planned, and the time that is required to implement them. In the event that data from the watershed-wide water quality monitoring program indicate that water quality objectives for nutrients are still being exceeded after the CNRP is fully implemented.

1.4.2 Applicability

The applicability of this CNRP is limited to the MS4 Permittees in the following jurisdictions: County of Riverside and the Cities of Beaumont, Canyon Lake, Hemet, Menifee, Moreno Valley, Murrieta, Perris, Riverside, San Jacinto, Lake Elsinore and Wildomar[4].

1.4.3 Compliance with Urban Wasteload Allocation

The Riverside County MS4 Permittees have developed a CNRP that is designed to achieve compliance with the urban WLAs by the compliance date of December 31, 2020. Per MS4 permit Section VI.D.2.k, compliance with the urban WLAs can be measured using one of the two following methods:

- Directly, using relevant monitoring data and/or approved modeling procedures to estimate actual nitrogen and phosphorus loads being discharged to the lakes, or,

- Indirectly, using water quality monitoring data and other biological metrics approved by the Regional Board, to show water quality standards are being consistently attained (as measured by the response targets identified in the Nutrient TMDLs).

Compliance with the urban WLAs may also be accomplished through the trading of pollutant allocations among sources to the extent that such allocation tradeoffs optimize point and non-point source control strategies to achieve the compliance in an efficient manner.

1.4.4 CNRP Conceptual Framework

Based on the analysis contained herein, compliance with the urban WLAs will require implementation of nutrient mitigation activities in both the watershed and the lakes. Accordingly, the CNRP is built around a framework that includes both watershed-based BMPs and in-lake remediation activities. Coupled with this framework is a monitoring program to evaluate progress towards compliance with urban WLAs and an adaptive implementation program to provide opportunity to make adjustments to the CNRP, where deemed necessary to achieve the urban WLAs.

- *Watershed-based BMPs* – The CNRP identifies the specific ordinance(s) and BMPs that will be implemented by the MS4 Permittees in the watersheds that drain to Lake Elsinore or Canyon Lake. These activities focus on targeting and mitigating nutrients at their source, prior to discharge during wet weather events.

- *In-lake Remediation Projects* – A significant source of nutrients to Lake Elsinore and Canyon Lake are nutrient releases from in-lake sediments. Practical remediation projects for reducing or managing sediment releases of nutrients have been identified and incorporated into the CNRP. In some cases these projects are already ongoing; in others, new project activities will be initiated. The CNRP identifies the MS4 Permittee commitments to the implementation of these projects, in terms of the commitment to initiate the project through capital expenditures and the long-term commitment to the operation and maintenance of the project.

- *Monitoring Program* – The original monitoring program (Lake Elsinore, Canyon Lake and San Jacinto watershed) established in 2006 was modified in 2010 to allow resources dedicated to

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[4] An agreement with the San Diego Regional Water Quality Control Board ("San Diego Regional Board") allows the cities of Wildomar and Murrieta to be wholly regulated by the Santa Margarita Region MS4 permit issued by the San Diego Regional Board; however, these cities continue to be subject to the TMDL requirements of the Santa Ana Region MS4 permit (RWQCB, San Diego Region, 2010).

monitoring activities to be used to support implementation of in-lake remediation projects. Further reductions in monitoring were discussed with Regional Board staff and documented in correspondence from Regional Board staff to the TMDL Task Force dated September 2, 2011. Under the CNRP, monitoring will continue to be implemented at a reduced level through FY 2014-2015 to facilitate dedicating resources to necessary in-lake projects. In FY 2015-2016, monitoring will be increased to provide sufficient data to evaluate progress towards achieving the urban and septic WLAs and LAs or lake water quality response targets. Section 2.2.3 describes the monitoring program that will be implemented as part of the CNRP.

- *Special Studies* – The CNRP describes several special studies that may be undertaken by the MS4 Permittees to support changes to the CNRP and/or the TMDL. Execution of these studies is optional and at the discretion of the MS4 Permittees. If the Permittees decide to implement any of these studies, efforts will be coordinated with the Regional Board and Task Force.
- *Adaptive Implementation* – Implementation of the CNRP will be an iterative process that involves implementation of watershed BMPs and in-lake remediation projects followed by monitoring to assess compliance with urban and septic WLAs and LAs or lake water quality response targets. As additional data become available, the CNRP may need to be revised as part of an adaptive implementation process.

1.4.5 CNRP Development Process

The CNRP was developed by the MS4 Permittees subject to the TMDL requirements. In parallel with and prior to CNRP development, the Permittees have actively participated in TMDL related implementation activities (e.g., see Attachment A). Coordination activities since January 2010 have included:

Management Steering Committee Meetings

- May 20, 2010
- August 19, 2010
- October 21, 2010
- May 19, 2011

LE/CL TMDL Task Force Meetings

- January 25, 2010
- February 22, 2010
- April 12, 2010
- June 28, 2010
- August 23, 2010
- February 22, 2011
- April 19, 2011
- May 31, 2011
- July 12, 2011
- January 23, 2012
- February 14, 2012
- March 27, 2012
- April 23, 2012
- May 21, 2012
- June 18, 2012
- August 21, 2012
- September 19, 2012
- January 23, 2013

LE/CL TMDL Task Force Technical Advisory Committee Meetings

- August 4, 2010
- September 27, 2010
- October 25, 2010
- November 18,2010

- December 15, 2010
- March 22, 2011
- April 6, 2011
- May 18, 2011
- June 14, 2011
- August 15, 2011
- September 13, 2011
- October 19, 2011
- November 15, 2011
- December 12, 2012

Other TMDL-related Meetings

- October 5, 2011 – LESJWA TMDL Workshop
- November 17, 2011 – Western Riverside Council of Governments Technical Advisory Committee Meeting - Presentation to Riverside County City Managers
- December 7, 2011 – Presentation to Canyon Lake City Council

1.4.6 CNRP Roadmap

The CNRP is presented in two parts: (1) primary sections that provide an executive level summary of the components, schedule, strategy, and technical basis for the CNRP; and (2) supporting attachments that provide additional information to support the primary sections. Following is a summary of the purpose and content of each part of the CNRP:

- ***Section 2*** – Describes the CNRP program elements, the CNRP implementation schedule and the incorporation of an adaptive implementation strategy into the plan.
- ***Section 3*** – Provides the technical basis for the conclusion that full implementation of the CNRP will achieve compliance with the urban and septic WLAs and LAs or lake water quality response targets applicable to each lake.

The above sections are supported by the following attachments:

- ***Attachment A, TMDL Implementation*** – Documents TMDL implementation activities completed to date by the Task Force and MS4 Permittees.
- ***Attachment B, Watershed Characterization*** – Provides background information regarding the general characteristics of the watersheds draining to Canyon Lake and Lake Elsinore and existing water quality in each lake.
- ***Attachment C, Canyon Lake Nutrient TMDL In-Lake Strategies Evaluation*** – Provides additional information to support the selection and prioritization of in-lake remediation projects for Canyon Lake.
- ***Attachment D, Existing Nutrient Source Control Programs*** - Documents existing MS4 permit activities that have been implemented by the MS4 permit program that reduce the runoff of nutrients to Canyon Lake and Lake Elsinore.
- ***Attachment E, Implementation Schedule*** – Provides additional information regarding the implementation schedule summarized in Section 2.3.
- ***Attachment F, References***

Section 2
CNRP Implementation Program

2.1 Introduction

The MS4 Permittees have been actively participating in the implementation of the Nutrient TMDLs through the activities of the Task Force since 2006. Substantial effort, e.g., data collection, in-lake and watershed modeling, program development and BMP implementation, have been completed to date. This compilation of work provides the foundation for this CNRP, which establishes the additional actions that will be carried out by MS4 Permittees to achieve compliance with the urban and septic WLAs and LAs or lake water quality response targets.

The MS4 Permittees will achieve compliance with the urban and septic WLAs and LAs or lake water quality response targets applicable to the Lake Elsinore and Canyon Lake through a combination of watershed-based BMPs and in-lake remediation projects. For the most part, the watershed-based BMPs implemented under the CNRP will be an extension or continuation of ongoing BMP implementation carried out by the MS4 program and individual Permittee jurisdictions. For example, an extension may be the revision of ordinances to provide tighter controls on nutrient sources in the watershed or the implementation of newly required low impact development (LID)-based BMPs in all new development or significant redevelopment projects. A continuation of a BMP would include existing public education and outreach (PEO) activities that already target nutrient sources.

While some watershed-based BMP implementation activities are expected to be generally uniform across the area, e.g., through implementation of area-wide MS4 programs, others may vary by jurisdiction, i.e., implementation is dependent on each Permittee’s current local program, available resources and opportunities, and local sub-watershed needs. Each Permittee’s LIP will describe in more detail the specific actions that will be taken by the Permittees to address CNRP implementation requirements.

In addition to the watershed-based BMPs implemented through the area-wide MS4 program or by local Permittee jurisdictions, the CNRP identifies specific in-lake remediation projects and monitoring activities planned for implementation under the CNRP. These CNRP elements will be implemented collectively by all MS4 Permittees subject to the requirements of the TMDLs.

This CNRP supersedes all other plans for the CL/LE Nutrient TMDL, including previous version of the CNRP and monitoring plans. The following sections describe the key elements contained in this CNRP and provide an implementation schedule to achieve compliance by December 31, 2020. Where necessary, CNRP attachments provide supplemental information.

2.2 CNRP Program Elements

CNRP implementation consists of the following key implementation activities:

- Watershed-based BMPs to reduce nutrient loading in urban runoff, primarily wet weather flows.
- In-lake remediation projects to mitigate nutrient impacts from in-lake sediments or external loads in suspension. Separate remediation projects are included for Lake Elsinore and Canyon Lake.
- Monitoring activities to assess compliance with TMDL.
- Optional special studies to develop data to support BMP implementation or provide the basis for revisions to the TMDL.

Each of these implementation activities is described in more detail below. In addition to these activities, the CNRP program includes an adaptive implementation element to provide opportunity to make changes to the CNRP or TMDL as more information is developed over time.

2.2.1 Watershed-based BMPs

The level of implementation of watershed-based BMPs will vary by MS4 Permittee. As will be discussed in Section 3, the estimated number of acres requiring implementation of watershed-based BMPs varies considerably from one Permittee to another. Given the range of watershed-based BMPs available for implementation and the specific exposure of individual Permittees to the TMDL (due to geographic location, portion of jurisdiction subject to TMDL, etc.), each Permittee will determine the degree to which it will incorporate a particular BMP into its TMDL compliance activities. For example, one Permittee may determine that increased emphasis on street sweeping/debris removal BMPs provides the needed nutrient source reduction that it needs to comply with its WLA. Another Permittee may find that other programs such as pet waste management or better management of fertilizer use provides the necessary load reductions.

Watershed-based BMPs include both non-structural programmatic BMPs and post-construction BMPs associated with the implementation of WQMP requirements for new development and significant redevelopment activities. The CNRP accounts for water quality improvements that have already occurred since TMDL adoption (January 1, 2005, see Attachment D) and anticipated improvements expected from implementation of specific non-structural program elements in the future (see Section 2.2). Watershed-based BMPs include the following activities:

- Ordinance Development and/or Implementation where necessary
- Street Sweeping/Debris Removal
- Low Impact Development and Land Use Conversion (WQMP Implementation)
- Septic System Management
- Public Education and Outreach
- Inspections and Enforcement

The CNRP quantifies the expected water quality benefits associated with implementation of street sweeping/debris removal, septic system management and WQMP implementation. The remaining BMPs, ordinance development, public education and outreach, and inspections and enforcement, provide water quality benefits, but these benefits were not quantified as part of the compliance analysis. Instead, implementation of these BMPs provides a planned additional margin of safety with regards to the compliance analyses completed as part of this CNRP.

Post-construction LID-based BMPs required for new development and significant re-development projects are the only structural watershed-based BMPs currently included in the CNRP. The newly developed WQMP requirements ensure that a portion of the wet weather runoff will be contained onsite for all future development projects subject to WQMP requirements[5]. Implementation of WQMP requirements over time coupled with the in-lake remediation projects (described below) are expected to provide sufficient mitigation of nutrients. However, if over time it is determined that additional watershed-based structural BMPs are necessary (as would be determined through the adaptive implementation process, as described in Section 2.4), then specific structural BMP projects could be identified. The Permittees are currently conducting retrofit studies of their MS4 systems that will help develop a list of additional structural watershed controls that can be considered in the future if needed.

If additional structural watershed-based BMPs are needed, then the project would be implemented according to the Capital Improvement Project (CIP) Process, as described in Figure 2-1. Because the completion of the CIP process, from project identification through construction, requires adequate funding, completion of the California Environmental Quality Act (CEQA) process, and obtaining all appropriate permits and approvals, the timeline associated with implementation of a watershed-based structural BMP may be lengthy.

The following sections provide additional information regarding each of the watershed-based BMPs incorporated into the CNRP.

2.2.1.1 Ordinances

The CNRP requires the identification of specific ordinances that when implemented will reduce nutrient loads from various urban sources in the watershed (MS4 permit *Section VI.D.2.d.i.(a)*) Implementation of this CNRP element will occur either through the adoption of a new ordinance or modification of an existing ordinance. Decisions regarding the use of ordinances to reduce nutrients will be made at the individual Permittee level. Some MS4 Permittees may choose to make no changes to their ordinances.

Three types of ordinances are included in the CNRP for evaluation by the individual MS4 Permittee jurisdictions: Pet waste, Fertilizer Application Management, and Yard Waste Management (leaf litter). The following sections provide additional information regarding potential use of each ordinance type as a tool to manage nutrients at the local level.

Pet Waste Ordinance

Purpose – Evaluate existing ordinances to determine need to improve management of animal wastes to reduce nutrients in urban runoff from entering MS4 storm drains.

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[5] The MS4's revised WQMP guidance and template are currently under review by the Regional Board; however, Regional Board approval and full-scale implementation are expected to coincide with the implementation of this CNRP.

Figure 2-1 Typical MS4 Permittee's Capital Improvement Project (CIP) Process

Project Identification - Identification of a CIP project occurs through one of two mechanisms:

- Public agency assessment of a particular site's current conditions to evaluate the need for structural improvements. These needs may be identified from observations of agency staff, routine maintenance / replacement schedules, or other sources internal to the agency.
- Receipt of public complaints (presented directly to agency staff or a governing body) regarding an infrastructure concern (e.g., potholes, street flooding), which may result in a site investigation. Based on the outcome of the investigation, an agency may decide that a project needs to be constructed.

Budgeting / Planning - After a project need has been established, staff implement a process to have the proposed project included in the CIP. Agency staff begins preliminary planning steps to verify the viability of the project and prepares a cost estimate, which along with other new or ongoing infrastructure needs, is used to prioritize the project based on public need, necessity and available funds. This phase typically involves both project planning and preparation of a preliminary design to support development of the cost estimate. With a project budget prepared, staff seeks approval to incorporate the project in the CIP. In some cases preliminary planning efforts may determine that a proposed project is not viable due to environmental constraints, community opposition, engineering limitations or other factors. In such cases a project is typically abandoned and alternative solutions are considered.

Design - Once a project is in the CIP, design work to prepare construction drawings and project specifications can begin. Based on project complexity, the time required to complete the design varies from less than a year to several years. During the design phase, and sometimes beginning in the budgeting / planning phase, staff initiates the CEQA process. Depending on the nature of the project or the need for special permits, obtaining CEQA approval can significantly affect the timeline to construct a project. Projects may also be abandoned in the design phase as the project is further refined. Factors such as changes to the project's preliminary design parameters, soils, groundwater and utility investigations, and regulatory issues can impact the viability of a project during its refinement in the design stage.

Permitting– During this phase, all required permits and approvals for construction are obtained. The process for obtaining permits and approvals typically begins during the design phase and sometimes begins as early as the budgeting / planning phase. Depending on the nature of the project or the need for special permits, obtaining all required permits and approvals can significantly affect the timeline to construct a project and in some cases result in cancellation of the project. If this occurs, then alternative solutions are considered.

Construction– Construction can begin upon design completion, receipt of all required permits and approvals, completion of all administrative requirements and availability of funds. Depending on the complexity and size of the project, right of way acquisition timelines, CEQA documentation and approvals, and involvement of other agencies, e.g., utilities, the construction phase can take anywhere from a few months to several years.

Implementation Approach - Apart from the City of Canyon Lake's recently adopted pet waste disposal ordinance (Ordinance No. 138U), existing ordinances do not establish specific requirements to properly dispose of pet waste with accompanying penalties for failure to comply. As part of CNRP implementation, the Permittees will evaluate existing ordinances that address any type of animal waste and examine ways to enhance waste management requirements, compliance, and enforcement. For example, a control ordinance could specifically require owners/keepers of pets to properly dispose of pet waste that is deposited on any property, whether public or private. Proper disposal would be defined as placement of pet waste in waste receptacles or containers that are regularly emptied or to a sanitary sewage system for proper treatment. Penalties or fines could be also included.

The evaluation of the need for pet waste ordinance would be coordinated with the Riverside County MS4 permit requirement for MS4 Permittees to evaluate the need for modifications to existing ordinances or establishment of a new ordinance to manage pathogens or bacterial indicators:

- *Riverside County MS4 Permit Section VIII.C* – "Within three (3) years of adoption of this Order, the Co-Permittees shall promulgate and implement ordinances that would control known pathogen or Bacterial Indicator sources such as animal wastes, if necessary."

With a permit adoption date of January 29, 2010, this MS4 permit requirement must be addressed by January 29, 2013. While the emphasis of the permit language is on pathogens or bacterial indicators, adoption of an ordinance to manage animal wastes can also reduce a potentially important source of nutrients in the watershed.

Expected Benefits – Establishing requirements to manage animal wastes in a manner that reduces opportunity for nutrients contained in these wastes to be mobilized in urban runoff reduces nutrients potentially discharged to receiving waters through the MS4. Given variable levels of implementation by jurisdiction, the expected water quality benefits of this BMP have not been quantified; instead the benefits are included in the margin of safety.

Fertilizer Management Ordinance

Purpose – Evaluate existing ordinances regarding the appropriate use and management of fertilizers within the local jurisdiction.

Implementation Approach – Currently, existing ordinances do not regulate the content of manufactured fertilizers as applied within the jurisdictions. Under this element, the MS4 Permittees will evaluate and consider adoption of new ordinances to include lawn application control, specifically, the content of phosphorus in commercial fertilizers[6].

Expected Benefit – Establishment of fertilizer application ordinances reduces the source of phosphorus available to runoff from lawn or turf areas in the watershed. Given variable levels of implementation by jurisdiction, the expected water quality benefits of this BMP have not been quantified; instead the benefits are included in the margin of safety.

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[6] Examples of this type of fertilizer ordinance are codified in the Cities of Ann Arbor, Michigan (Ord. No. 1-06) and Plymouth, Minnesota (City Code 1170.05). In the City of Ann Arbor, the fertilizer ordinance regulates the use and application of manufactured fertilizer containing phosphorus. The ordinance also requires commercial applicators or institutional applicators (e.g., those applying fertilizer to parks, schools, etc.) to sign a sworn statement abiding by the ordinance and to submit fertilizer samples upon request. The ordinance does allow for exemptions in cases where soil testing shows phosphorus levels to be insufficient for turf growth or for applications on newly established or developed turf areas in the first growing season. For a three year period following the implementation of the Ann Arbor ordinance limiting application of lawn fertilizers containing phosphorus, Lehman at al. (2011) reported statistically significant reductions in total phosphorus (TP) to the Huron River. TP showed an average reduction from 11 to 23 percent at monitored study sites.

Yard Waste Management Ordinance

Purpose – Evaluate existing ordinances which regulate the depositing of yard waste debris into the MS4.

Implementation Approach - The Permittees have existing legal authority within each jurisdiction establishing stormwater ordinances to prohibit the depositing of yard waste into the MS4. Permittees will review these existing ordinances to evaluate ways to enhance public education or inspection/enforcement activities to provide additional reductions in nutrients from these sources. For example, approaches to better manage these potential nutrient sources include establishing yard waste/leaf blowing requirements for commercial yard businesses, sweeping and returning yard clippings to lawn areas, collecting and disposing yard wastes for green recycling, or recycling yard waste by composting.

Expected Benefit - Reducing the volume of yard waste blown into or washed into the MS4 decreases the nutrient load to downstream waters. Given variable levels of implementation by jurisdiction, the expected water quality benefits of this BMP have not been quantified; instead the benefits are included in the margin of safety.

2.2.1.2 Specific Watershed-based BMPs

The MS4 permit requires that the CNRP identify the specific BMPs that, when implemented, will reduce the concentration of urban nutrient sources in the watershed (MS4 permit Section VI.D.2.d.i.(b)). The following sections describe each of the specific watershed-based BMPs included in the CNRP. Section 3 describes the expected water quality benefits, where such benefits may be quantified. As noted above, the level of implementation of each of these BMPs will be determined by the local jurisdiction.

Under this BMP, the MS4 Permittees will evaluate existing street sweeping and MS4 facility cleaning programs to determine if ongoing programs can be enhanced to further reduce presence of nutrient sources on street surfaces and MS4 facilities.

Street Sweeping and Debris Removal

Purpose – Street sweeping and MS4 facility debris removal activities reduce a significant source of nutrients in urban environments.

Implementation Approach – The MS4 Permittees will continue to perform street sweeping, MS4 facility inspections and cleaning programs for storm drain pipes, catch basins and storm channels. Under this BMP element, each Permittee will review their existing programs (e.g., methods, frequency of implementation, and equipment use) to evaluate the potential to modify these programs to further reduce nutrient loads from streets and MS4 facilities. Where opportunities exist, Permittees will evaluate the feasibility of implementing changes to their programs. If it is determined that a change in equipment will provide water quality benefits, the Permittees will work with their respective governing bodies to request funding to upgrade/replace equipment.

Expected Benefits – Existing street sweeping/debris removal practices have already provided important reductions from these nutrient sources in the watershed. Given the important benefits of these types of BMPs, a review of these programs could identify additional opportunities to further reduce nutrients from these sources. Quantification of the water quality benefits is provided in Section 3.

Septic System Management

Purpose – Continue ongoing efforts to reduce nutrients associated with the use of septic systems in the watershed.

Implementation Approach – Task 6 of the TMDL Implementation Plan required the County of Riverside and Cities of Perris, Moreno Valley, and Murrieta to collectively or individually develop and submit to the Regional Board a Septic System Management Plan (SSMP) to identify and address nutrient discharges from septic systems within the San Jacinto watershed. This plan, *San Jacinto Onsite Wastewater Management Program report*, was submitted to the Regional Board on November 17, 2007. The County and Cities are currently implementing the plan in their respective jurisdictions. In addition, the City of Perris is currently implementing a project to convert septic to sewer in the Enchanted Heights area of the City. There are also plans for septic conversions in other areas of the San Jacinto Watershed, including Quail Valley. However, these other plans are not finalized yet and therefore are not credited for load reduction in the CNRP. Should additional septic systems be converted to sewer, these activities would be reported and credited in future annual reports on CNRP implementation.

The SSMP was also intended to incorporate pending regulations from the State Water Resource Control Board (State Board). The State Board is developing a Water Quality Control Policy for Siting, Design, Operation, and Management of Onsite Wastewater Treatment Systems (OWTS or “septic systems”) (“OWTS Policy”). The OWTS Policy is being developed pursuant to California Assembly Bill 885 (AB 885). The State Board released a draft OWTS Policy for public comment on September 30, 2011. The draft policy establishes a multi-tiered regulatory system for the management of septic systems. For example, Tier 3 (Impaired Areas) includes specific performance requirements for new or replacement OWTS in areas near waterbodies impaired for pathogens or nitrogen (unless it is determined that the OWTS is not contributing to a local water quality problem). Tier 4 (OWTS Requiring Corrective Action) establishes requirements for septic systems that are failing. When finalized, implementation of the State Board’s OWTS Policy will support efforts to reduce impacts from OWTS in the area covered by the CNRP.

Expected Benefits – Implementation of this BMP (as required currently or as will be required following State Board adoption of the OTWS Policy) reduces the potential for leakage from septic systems to contribute nutrients to the MS4 during wet weather conditions. The Section 3 Compliance Analysis quantifies the expected benefits from septic to sewer conversions as well as improved management of septic systems at risk of failure.

Low Impact Development (LID) and Land Use Conversion

Purpose – The MS4 Permit requires the implementation of LID practices to reduce runoff from new development and significant redevelopment activities. Implementation of these practices over time will reduce the nutrient load during wet weather runoff events.

Implementation Approach – Each of the MS4 Permittee jurisdictions include areas of open space , agricultural lands and other non-urban land uses that are expected to be converted to urban land use over the next ten years. This land use conversion can result in significant positive or negative effects to nutrient loading to the lakes. BMPs, including LID BMPs, that are required of new development and significant redevelopment projects (as defined in Board Order R8-2010-0033) help to offset the negative loading impacts of urbanization. The MS4 program recently revised its WQMP to incorporate the new LID requirements for development activities. The WQMP was submitted to the Regional Board July 29, 2011 and was approved on October 22, 2012. The WQMP takes full effect on April 22, 2013.

Expected Benefits – WQMP implementation has already provided water quality benefits throughout the watershed since TMDL adoption in December 2004. The compliance analysis incorporates these benefits by taking into account where BMPs have been implemented for removal of nutrients. As each MS4 Permittee jurisdiction develops, i.e., approves projects that convert non-urban areas to urban land uses or projects that redevelop existing urban areas, implementation of the new LID-based BMP requirements will provide additional water quality benefits. Section 3, Compliance Analysis, describes how these benefits were incorporated into the CNRP.

Public Education and Outreach

Purpose –Continue implementation of PEO activities that target nutrients as a pollutant of concern

Implementation Approach – The MS4 program has developed an extensive PEO program that targets nutrient sources that impact wet weather water quality, specifically – sediment management, fertilizer management and pet waste (see Attachment D). These PEO programs will be regularly evaluated and updated as needed to continue efforts to communicate the need to manage nutrients at the source, especially on commercial and residential properties. This BMP will be coordinated with the ordinance BMP, described above. If cities decide to modify existing or establish new ordinances to improve management of nutrient sources, PEO materials will be updated to communicate the new requirements to city or county residents and businesses.

Expected Benefits – Increased awareness of pollutant sources reduces nutrients at the source, thus minimizing the opportunity for nutrients to be mobilized during wet weather events. Given the difficulty of equating PEO impressions to specific reductions in nutrient loads, the expected water quality benefits of this BMP have not been quantified; instead the benefits are included in the margin of safety.

Inspections and Enforcement

*Purpose –*Continue implementation of inspection and enforcement programs that target activities that can contribute pollutants, in particular nutrients, to storm drains.

Implementation Approach – Each MS4 Permittee has an active inspection and enforcement program to comply with MS4 permit requirements applicable to their jurisdictions. These programs will continue to be implemented (see Attachment D). This BMP will be coordinated with the ordinance BMP, described above. If cities decide to modify existing or establish new ordinances to improve management of nutrient sources, inspection and enforcement programs will be reviewed, and if necessary modified, to implement new ordinance requirements.

Expected Benefits – Inspection and enforcement activities help ensure compliance with local stormwater management requirements, which maximizes the potential benefits of BMP implementation. Given the year-to-year variability in inspection activities and potential follow-up enforcement actions, the expected water quality benefits of this BMP have not been quantified; instead the benefits are included in the margin of safety.

2.2.2 In-Lake Remediation Activities

The MS4 permit requires that the CNRP identify the specific regional treatment facilities and the locations where such facilities will be built to reduce the concentration of nutrients discharged from urban sources and the expected water quality improvements to result when the facilities are complete (MS4 Permit Section VI.D.2.d.i.(d)). The CNRP includes implementation of in-lake remediation activities that serve as regional treatment facilities for Canyon Lake and Lake Elsinore. The following sections describe the remediation activities planned for each lake; information regarding the expected water quality improvements to result from implementation of these activities is provided in Section 3.

Canyon Lake

Numerous studies have been conducted by the Task Force to evaluate potential in-lake nutrient management BMPs for Canyon Lake, including addition of chemicals; alum, Phoslock, and zeolite, and construction of aeration or hypolimnetic oxygenation. The most recent studies are summarized in Attachment C. They provide the basis for the selected in-lake BMPs. Table 2-1 provides a matrix showing how two selected in-lake BMPs for inclusion in the CNRP perform in meeting either WLAs or LAs for urban and septic sources or TMDL numeric targets for causal and response variables. The basis for these determinations is provided by modeling studies conducted in 2012 (Attachment C).

Table 2-1. Matrix Comparing Effectiveness of HOS and Alum In-Lake Nutrient Management BMPs for Compliance with the TMDL, per the MS4 Permit

Criteria	Constituent	HOS	Alum
WLA/LA	TP	■	■
	TN	■	□
TMDL Numeric Targets	TP (causal)	□	■
	TN (causal)	□	□
	Chlorophyll-a (response)	□	■
	Dissolved Oxygen (response)	■	◪

Key: Filled in square denotes an expectation that the target will be achieved, partially filled square denote an expectation of signifcant improvement, but not enough to achieve target as currently described in TMDL, and blank boxes indicate targets that are not effectively managed

To comply with the TMDL, the MS4 Permittees must either demonstrate that 1) WLAs and LAs for urban and septic sources can be achieved with implementation of a project or 2) that the project will improve lake water quality to protect water quality standards, as measured by TMDL response targets for chlorophyll-a and DO. Incubation studies and subsequent models specific to Canyon Lake suggest that the HOS would suppress sediment nutrient flux to offset enough watershed loads to bring the MS4 Permittees into compliance with the WLA for urban and LA for septic sources. However, Anderson 2012b determined that exceedences of the chlorophyll-a response target would continue to occur if only HOS were to be implemented in the lake. In its March 31, 2012 comment letter, the Regional Board states that if allocations are met by all dischargers, but in-lake water quality response targets are not achieved, then the TMDL will be reconsidered and allocated loads may be further reduced. Thus, the Permittees opted to prioritize in-lake BMPs based on their effectiveness in meeting the TMDL response targets for chlorophyll-a, and DO.

Adding alum to Canyon Lake was estimated to be highly effective in achieving the interim and final chlorophyll-a response target; therefore to control algae in the lake, the Permittees plan first conduct five alum applications over a two-year period (see Section 3.4.2). By binding phosphorus and reducing algae growth, the continued use of alum will reduce the cycling of nutrients and associated sediment oxygen demand in the lake bottom. Accordingly, the changes in biogeochemical processes will indirectly increase DO in the hypolimnion, and may be sufficient to achieve the interim and final DO response target.

The effectiveness of in-lake remediation using alum addition will be evaluated as part of the adaptive management process incorporated into this CNRP (see Section 2.4). If it is found that a combination of watershed BMPs and alum additions are not sufficient to meet the final DO response target, then the Permittees plan to implement additional in-lake solutions which can include aeration and/or HOS, if necessary. These additional in-lake BMPs would be constructed to provide the additional oxygen needed to meet the DO final response target. This is expected to be a much smaller scale than if the HOS was used for suppression of sediment nutrient flux.

Lake Elsinore

Work completed through the Task Force identified several recommended Phase 1 in-lake remediation activities, as well as potential supplemental BMPs, for deployment in Lake Elsinore (*In-Lake Sediment Nutrient Reduction Plan for Lake Elsinore*, October 22, 2007). Of these remediation activities, the CNRP includes participation in the operation of the in-lake aeration system. This in-lake aeration/mixing system was installed in Lake Elsinore in two phases. The first phase, implemented by LESJWA in 2005, involved the construction of axial flow water pumps to improve lake circulation. A second phase, implemented in 2007, involved construction of an in-lake aeration project designed to pump air through a system of twelve perforated pipelines submerged along the bottom of lake. The intent of the aeration system is to improve circulation so that oxygen levels are better distributed throughout the water column. The bubble diffuser "lifts" oxygen-deficient bottom waters to the surface where it can be re-saturated through direct contact with the atmosphere.

Through agreements established with other stakeholders and as part of CNRP implementation, the MS4 Permittees will participate in the operation of the in-lake aeration system. At this time, based on lake modeling and compliance analyses, the MS4 Permittees believe the aeration system will provide the necessary nutrient load reductions to comply with urban WLAs. In the event that additional BMPs are necessary, the *In-Lake Sediment Nutrient Reduction Plan for Lake Elsinore* (October 22, 2007) identified a number of other in-lake control strategies. Of these strategies, participation in fishery management activities or the application of metal salts, are the preferred next steps if additional BMPs are necessary.

Similar to Canyon Lake, the Permittees are continuing to evaluate alternative compliance options should the Permittees determine that an alternative compliance approach is needed to achieve in-lake response targets for Lake Elsinore. If the Permittees determine that an alternative compliance approach is necessary, the Permittees may propose revisions to this CNRP to incorporate the alternative compliance approach.

2.2.3 Monitoring Program

The MS4 permit requires that the CNRP include inspection criteria that will be used to identify and manage the urban sources most likely causing exceedences of urban WLAs for nutrients (MS4 permit Section VI.D.2.d.i.(c)). This requirement will be fulfilled through (a) implementation of watershed and in-lake monitoring programs (MS4 permit Section VI.D.2.g); and (b) the requirement to provide a summary in the MS4 program's Annual Report of all relevant data from water quality monitoring programs and an evaluation of compliance with the Nutrient TMDLs by reporting the effectiveness of the BMPs implemented in the watershed to control nutrient inputs into the lake from urban runoff (MS4 Permit Section VI.D.2.h).

Monitoring activities have been implemented in a phased manner since adoption of the TMDL. The following sections provide a brief history of the monitoring program and expectations for continued monitoring under the CNRP.

Phase 1 Monitoring

The MS4 Permittees, as participants in the Task Force, have conducted water quality monitoring on Lake Elsinore and Canyon Lake since 2006. The Task Force prepared the *Lake Elsinore and Canyon Lake*

Nutrient TMDL Monitoring Plan ("Monitoring Plan") in February 2006. Monitoring began after the Regional Board approved the Monitoring Plan in March 2006. This plan included three components:

- Lake Elsinore – Provide data to evaluate compliance with interim and final nitrogen, phosphorus, chlorophyll *a*, and dissolved oxygen numeric targets.
- Canyon Lake - Provide data to evaluate compliance with interim and final nitrogen, phosphorus, chlorophyll *a*, and dissolved oxygen numeric targets.
- San Jacinto River watershed – Provide data to evaluate compliance with interim and/or final nitrogen and phosphorus TMDL WLAs and load allocations.

The original monitoring program included a multi-phase approach:

- *Phase 1 (Intensive Lake Elsinore and Canyon Lake Study)* - Phase 1 focused on collecting data to evaluate in-lake processes and develop a linkage analysis to relate external pollutant loading to the in-lake response, e.g., with regards to nutrient concentrations. Phase 1 was scheduled to occur over a two to three-year period.
- *Phase 2 (Intensive Watershed Study)* - Phase 2 is an intensive watershed study that provides data to support compliance analyses and provide data to understand external nutrient source contributions from the watershed.
- *Phase 3 (Compliance Monitoring)* – Upon completion of Phases 1 and 2, a compliance monitoring phase would begin. Phase 3 monitoring would consist of an agreed upon base level of in-lake and watershed compliance monitoring based on the findings from the previous phases.

Revision to Phase 1 Monitoring

In December 2010, the Task Force, in consultation with the Regional Board, revised the Phase 1 monitoring program for Lake Elsinore and Canyon Lake. The revised Phase 1 program decreases the number of sample locations in these waterbodies. The watershed monitoring program was not revised. Table 2-2 summarizes the currently approved Phase 1 monitoring program elements.

Table 2-2. Phase 1 Monitoring Summary

Monitoring Program	Sample Stations	Sampling Frequency	Field Parameters	Laboratory Parameters
Lake Elsinore	Station E2 (lake center)	16 events/year: Monthly (Oct to May); Bi-weekly (June to September)	Temperature, dissolved oxygen, conductivity, pH, turbidity, and redux potential	Chlorophyll *a*, hardness, total phosphorus, soluble reactive phosphorus, total organic phosphorus, nitrogen (total N, nitrite + nitrate, Ammonia N, total inorganic nitrogen, total organic nitrogen, iron, and total dissolved solids
Canyon Lake	Station C7 (deep lake)	16 events/year: Monthly (Oct to May); Bi-weekly (June to September)		
	Station C8 (mid-lake)			
	Station C10 (east bay)			
San Jacinto River Watershed	Site 3 - Salt Creek at Murrieta Rd	Three storm events per wet season	Temperature, turbidity, pH	Total organic nitrogen, nitrite nitrogen, nitrate N, ammonia, total phosphorus, soluble reactive phosphorus, total suspended solids, chemical oxygen demand, biological oxygen demand
	Site 4 –San Jacinto River at Goetz Road			
	Site 6 – San Jacinto River at Ramona Expressway			
	Site 30 – Canyon Lake Spillway			
	Site 1 – San Jacinto River, Cranston Guard Station			

CNRP Monitoring Program

Through fiscal year 2014-2015 the Permittees propose to continue the existing Phase I watershed monitoring program (see Table 2-2). The Permittees also propose to eliminate existing in-lake monitoring programs through the same period to ensure that resources are dedicated to facilitating and constructing in-lake BMPs. The Permittees will propose a revised comprehensive watershed and in-lake monitoring program by December 31, 2014 for implementation in fiscal year 2015-2016.

2.2.4 Special Studies

As resources allow, the MS4 Permittees may implement a number of studies during CNRP implementation to provide additional data to support TMDL implementation efforts. These studies are optional; MS4 Permittees implementation of or participation in these studies (if initiated by other TMDL stakeholders) is solely at their discretion. Where implemented, the outcome from various analyses or studies would be used to support the adaptive implementation process (see Section 2.3). The purpose of such studies is to provide data to refine TMDL parameters, e.g., development of more accurate land use data, revisions to the TMDL watershed and lake models based on updated water quality and land use data, and technical data to support use of supplemental BMPs should the effectiveness of planned in-lake remediation strategies be lower than anticipated. The implementation and timing of such studies is solely at the discretion of the MS4 Permittees; however, implementation would consider regular triennial reviews of the TMDL and TMDL compliance milestones.

2.3 Adaptive Implementation

The MS4 permit requires that the CNRP be updated as needed based on BMP effectiveness analyses completed as part of annual reporting activities (MS4 permit Section VI.D.2.f). In addition, the MS4 permit requires that the CNRP provide descriptions of any additional BMPs planned, and the time required to implement those BMPs, in the event that monitoring data indicate that water quality objectives for nutrient are still being exceeded after the CNRP is fully implemented (MS4 permit Section VI.D.2.d.ii.(e)). These requirements will be addressed through the adaptive implementation process that has been incorporated into this CNRP.

This CNRP establishes a program to reduce urban sources of nutrients through the implementation of watershed-based BMPs and to reduce nutrients already entrained in Canyon Lake and Lake Elsinore through the application of in-lake remediation strategies. With regards to the in-lake remediation projects proposed for Lake Elsinore, the following has been stated previously:

> “It is unlikely that the stakeholders will implement the perfect solution on the first try. Rather, success will depend on an iterative process of developing mitigation projects, measuring results, updating the predictive models and refine the follow-on strategy. This process of "adaptive implementation" makes best use of scarce public resources and reduces the risk of unforeseen consequences by emphasizing incremental changes. Using the lake as a laboratory, successful projects can be repeated or expanded. Unsuccessful projects can be terminated and resources shifted to alternative approaches. Moreover, as additional data becomes available, the ability to accurately assess the lake's true potential, and the steps necessary to achieve that potential, will also improve.” (*In-Lake Sediment Nutrient Reduction Plan for Lake Elsinore*, October 22, 2007, page 28).

This statement applies to any of the proposed watershed-based BMPs and in-lake remediation projects in either Canyon Lake or Lake Elsinore. For example, the Permittees may determine prior to 2014 that Zeolite or other remediation tool will provide a more cost effective method to address urban nutrient loads and and/or attain in-lake response targets. If such a finding is made, the Permittees may propose a revision to the CNRP based on this new information.

The compliance analysis (Section 3) quantifies the expected water quality benefits from implementation of this comprehensive nutrient management program. Based on this analysis, the CNRP, when fully implemented, is expected to result in compliance with the TMDL. This finding is based on the quantified compliance analysis results coupled with the margin of safety associated with the implementation of watershed-based BMPs that could not be quantified. All analyses are based on currently available data, including what is known regarding the effectiveness of the various BMPs included in the CNRP.

Over time, through the monitoring program and information collected through the MS4 Permit Annual Report, additional data will be developed to evaluate the effectiveness of various CNRP elements. These data may be supplemented by additional information developed through the optional special studies described above. In total, new data and information will be used to annually report and assess the effectiveness of CNRP implementation. As part of this effort, the Permittees will prepare a trend analysis for the response targets and nutrient levels in Lake Elsinore and Canyon Lake by November 30, 2018. This analysis will be included in the fiscal year 2018-2019 MS4 Annual Report. Based on the outcome of this analysis, the Permittees will make recommendations for additional BMPs and a schedule for deployment of those BMPs for incorporation into a revised CNRP by June 30, 2019. Upon Regional Board approval, the Permittees will implement the revised CNRP.

If it is determined that additional BMP implementation will be necessary to comply with the TMDL requirements as stated in the MS4 Permit, it is anticipated that the focus will be on additional in-lake remediation strategies, rather than additional watershed-based BMPs. This expectation is based on what is most likely to be most cost effective in terms of implementation. Specifically, other than implementation of large regional structural projects in the watershed, which would be very costly and potentially not practical given the potential size of storm flows, additional watershed-based BMPs are not expected to provide needed water quality benefits in a cost effective manner. As noted earlier in this chapter, there are several additional in-lake options that may be considered for both Lake Elsinore and Canyon Lake.

2.4 Implementation Schedule

The MS4 permit requires that the CNRP include a detailed schedule that provides the following information:

- Identifies the discrete milestones, decision points and alternative analyses necessary to assess satisfactory progress toward complying with the MS4 Permit requirements for the CL/LE Nutrient TMDL by December 31, 2020.
- Indicates which agency or agencies are responsible for meeting each milestone.
- Establishes the specific metric(s) that demonstrate the effectiveness of the CNRP and acceptable progress toward complying with the MS4 Permit requirements for the CL/LE Nutrient TMDL by December 31, 2020

Figure 2-2 shows the overall tasks and schedule for CNRP implementation. Presented as a timeline, this figure illustrates the relationship among tasks over the period from 2012 through the December 31, 2020 compliance date. Attachment E provides the detailed information required above for each CNRP task.

The implementation schedule includes tasks associated with each of the following elements:'

- *Watershed-based BMPs* – This element includes six BMPs. Three of these BMPs (ordinance development, street sweeping & debris removal, and inspection & enforcement) include time for the evaluation and, if appropriate, revision to the program element (shown as a "Development Activity"). For example, the Permittees will evaluate the need to revise existing ordinances to provide better tools to target nutrient sources. If needed changes are identified, then the Permittees will need to work through the process to revise the ordinance per local requirements. Once development is complete, then the schedule shows the element as an "implementation activity". Two BMPs (PEO and septic system management) will continue to be implemented as currently prescribed, i.e., the BMP can be implemented now. The final watershed-based BMP (LID-based WQMP implementation) will be fully implemented on or before April 22, 2013.

- *In-Lake Remediation Activities*

  - *Lake Elsinore* – The in-lake aeration system is already being implemented in Lake Elsinore. As shown in the schedule, the MS4 Permittees propose to support continuation of aeration and mixing activities in the lakes through participation in cost-sharing agreements.

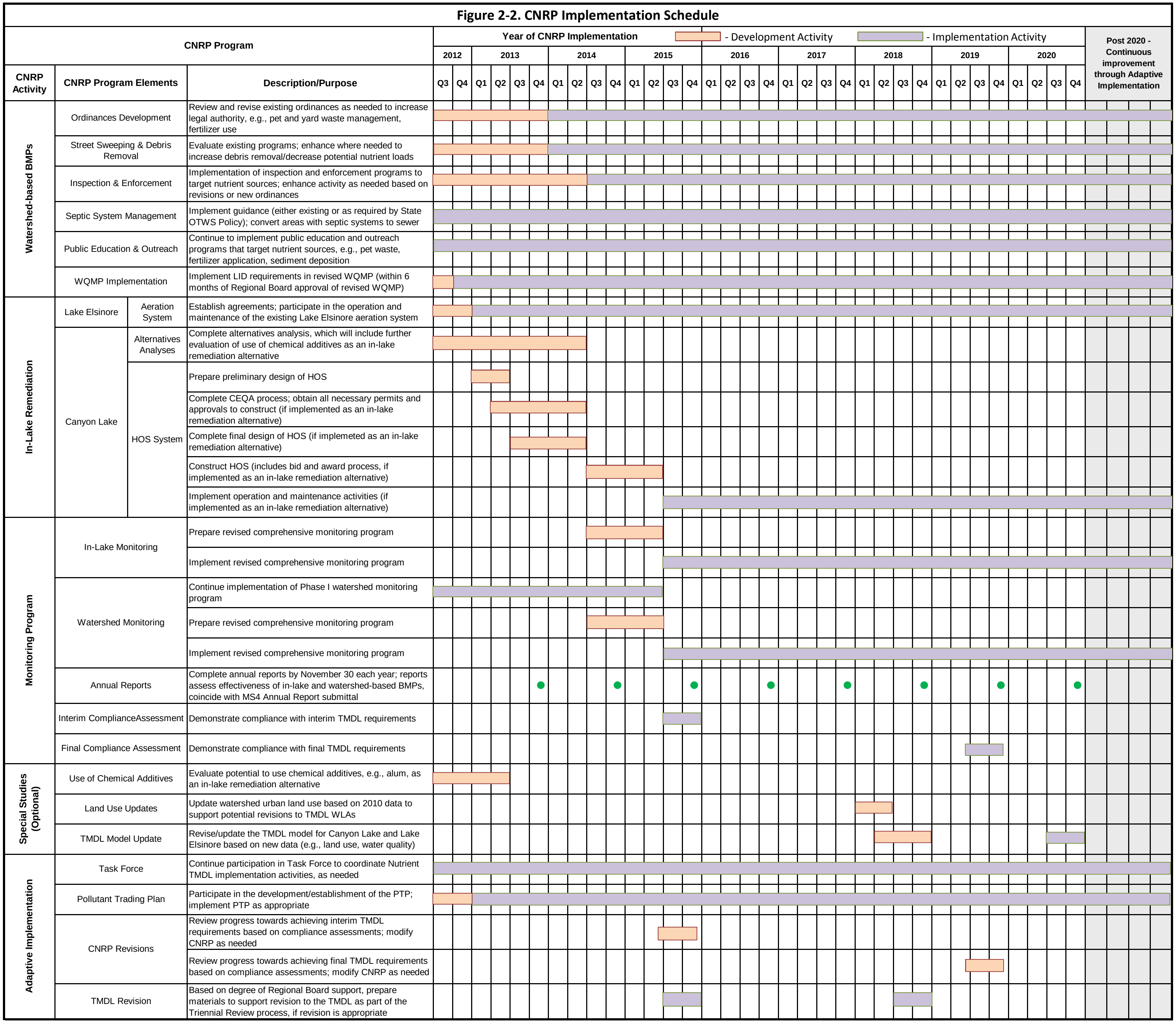
  - *Canyon Lake* – The MS4 Permittees propose to implement a series of five alum additions in Canyon Lake. The schedule establishes a development period (planning, operation agreements, toxicity testing, CEQA, and mobilization) that is expected be completed by September 2013 in time for the first alum application. This schedule is dependent on obtaining all required regulatory approvals for addition of alum to Canyon Lake in a timely manner.

- *Monitoring Program* –Watershed-based monitoring will continue as approved under the Phase I watershed monitoring program through fiscal year 2014-2015. By the end of 2014, the Permittees will propose a revised comprehensive watershed and in-lake monitoring program. If approved, this revised program will be implemented in fiscal year 2015-2016.

- Special Studies – The CNRP identifies special studies that may be implemented by the MS4 Permittees. The schedule for implementation of various studies is related to the need for new information that may be used to support the 2015 compliance assessment, need for any revisions to the CNRP, and anticipated TMDL triennial reviews, including evaluation of the appropriateness of the existing DO Target for Canyon Lake.

- Adaptive Implementation – This element includes TMDL implementation activities that could affect other stakeholders (e.g., TMDL revision, Task Force activities) and the potential need to revise the CNRP based on the findings from monitoring activities. The TMDL triennial review dates are based on the assumption that a triennial review will occur in 2015 and then every three years beyond 2015.

Figure 2-2. CNRP Implementation Schedule



CNRP Program

Year of CNRP Implementation

🟧 - Development Activity 🟪 - Implementation Activity

CNRP Activity	CNRP Program Elements		Description/Purpose	2012		2013				2014				2015				2016				2017				2018				2019				2020				Post 2020 - Continuous improvement through Adaptive Implementation
				Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	
Watershed-based BMPs	Ordinances Development		Review and revise existing ordinances as needed to increase legal authority, e.g., pet and yard waste management, fertilizer use	🟧	🟧	🟧	🟧	🟧	🟧	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪
	Street Sweeping & Debris Removal		Evaluate existing programs; enhance where needed to increase debris removal/decrease potential nutrient loads	🟧	🟧	🟧	🟧	🟧	🟧	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪
	Inspection & Enforcement		Implementation of inspection and enforcement programs to target nutrient sources; enhance activity as needed based on revisions or new ordinances	🟧	🟧	🟧	🟧	🟧	🟧	🟧	🟧	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪
	Septic System Management		Implement guidance (either existing or as required by State OTWS Policy); convert areas with septic systems to sewer	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪
	Public Education & Outreach		Continue to implement public education and outreach programs that target nutrient sources, e.g., pet waste, fertilizer application, sediment deposition	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪
	WQMP Implementation		Implement LID requirements in revised WQMP (within 6 months of Regional Board approval of revised WQMP)	🟧	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪
In-Lake Remediation	Lake Elsinore	Aeration System	Establish agreements; participate in the operation and maintenance of the existing Lake Elsinore aeration system	🟧	🟧	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪
	Canyon Lake	Alternatives Analyses	Complete alternatives analysis, which will include further evaluation of use of chemical additives as an in-lake remediation alternative	🟧	🟧	🟧	🟧	🟧	🟧	🟧	🟧																											
		HOS System	Prepare preliminary design of HOS			🟧	🟧																															
			Complete CEQA process; obtain all necessary permits and approvals to construct (if implemented as an in-lake remediation alternative)				🟧	🟧	🟧	🟧	🟧																											
			Complete final design of HOS (if implemeted as an in-lake remediation alternative)					🟧	🟧	🟧	🟧																											
			Construct HOS (includes bid and award process, if implemented as an in-lake remediation alternative)									🟧	🟧	🟧	🟧																							
			Implement operation and maintenance activities (if implemented as an in-lake remediation alternative)													🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪
Monitoring Program	In-Lake Monitoring		Prepare revised comprehensive monitoring program									🟧	🟧	🟧	🟧																							
			Implement revised comprehensive monitoring program													🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪
	Watershed Monitoring		Continue implementation of Phase I watershed monitoring program	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪																							
			Prepare revised comprehensive monitoring program									🟧	🟧	🟧	🟧																							
			Implement revised comprehensive monitoring program													🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪
	Annual Reports		Complete annual reports by November 30 each year; reports assess effectiveness of in-lake and watershed-based BMPs, coincide with MS4 Annual Report submittal						●				●				●				●				●				●				●				●	
	Interim ComplianceAssessment		Demonstrate compliance with interim TMDL requirements													🟪	🟪																					
	Final Compliance Assessment		Demonstrate compliance with final TMDL requirements																													🟪	🟪					
Special Studies (Optional)	Use of Chemical Additives		Evaluate potential to use chemical additives, e.g., alum, as an in-lake remediation alternative	🟧	🟧	🟧	🟧																															
	Land Use Updates		Update watershed urban land use based on 2010 data to support potential revisions to TMDL WLAs																							🟧	🟧											
	TMDL Model Update		Revise/update the TMDL model for Canyon Lake and Lake Elsinore based on new data (e.g., land use, water quality)																								🟧	🟧	🟧							🟪	🟪	
Adaptive Implementation	Task Force		Continue participation in Task Force to coordinate Nutrient TMDL implementation activities, as needed	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪
	Pollutant Trading Plan		Participate in the development/establishment of the PTP; implement PTP as appropriate	🟧	🟧	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪
	CNRP Revisions		Review progress towards achieving interim TMDL requirements based on compliance assessments; modify CNRP as needed													🟧	🟧																					
			Review progress towards achieving final TMDL requirements based on compliance assessments; modify CNRP as needed																													🟧	🟧					
	TMDL Revision		Based on degree of Regional Board support, prepare materials to support revision to the TMDL as part of the Triennial Review process, if revision is appropriate													🟪	🟪											🟪	🟪									

Section 3
Compliance Analysis

3.1 Introduction

The MS4 permit requires that the Permittees provide the scientific and technical documentation used to conclude that the CNRP, once fully implemented, is expected to achieve compliance with the urban WLA and septic LA for total nitrogen (TN) and total phosphorus (TP) by December 31, 2020 (MS4 permit Section VI.D.1.d.ii.(a)). The TMDL sets 10-year average WLAs for urban and LAs for septic sources of nutrients (Table 3-1) that will result in reductions needed to achieve numeric targets for response variables in Lake Elsinore and Canyon Lake (see Table 1-1). In the Nutrient TMDLs, sources with WLAs include urban, septic, reclaimed water, agriculture, and Concentrated Animal Feeding Operation (CAFO) sources. This compliance analysis only addresses the urban and septic WLAs associated with the MS4 Permittees and presumes other TMDL Stakeholders will reduce loads to their respective WLAs to achieve numeric targets in the lakes.

Table 3-1. Wasteload Allocations for Urban and Load Allocations for Septic Nutrient Sources in Canyon Lake and Lake Elsinore Watersheds

Nutrient Source	Canyon Lake		Lake Elsinore	
	TP (kg/yr)	TN (kg/yr)	TP (kg/yr)	TN (kg/yr)
Urban	306	3,974	124	349
Septic	139	4,850	69	608

Per MS4 permit Section VI.D.2.k, compliance with the urban WLAs can be measured using one of the following methods:

- Directly, using relevant monitoring data and approved modeling procedures to estimate 10-year average nitrogen and phosphorus loads being discharged to the lakes, or,
- Indirectly, using water quality monitoring data and other biological metrics approved by the Regional Board, to show water quality standards are being consistently attained (as measured by the response targets identified in the Nutrient TMDLs).

For the Lake Elsinore TMDL, this compliance analysis uses the direct method, with BMPs designed to reduce long-term average (running 10-year) annual nutrient load for urban and septic sources to allowable levels, set as WLAs and LAs in the TMDL. Conversely, the indirect method is used to demonstrate compliance with the Canyon Lake TMDL, with BMPs designed to achieve lake water quality response variables for annual average chlorophyll-a and daily average DO. By using the shorter term (annual for chlorophyll-a and daily for DO) response variables to demonstrate compliance in Canyon Lake, BMP implementation must account for wet years when watershed loads are much greater than the 10-year average.

3.1.1 Compliance Analysis Approach

The following sections provide detailed description of the methodology employed to demonstrate compliance with the WLAs for urban and septic sources. The analysis involved several key questions, including:

- What is the average load of nutrients from urban and septic sources in the Canyon Lake and Lake Elsinore watersheds?
  Development of the TMDL involved application of lake and watershed models to characterize nutrient sources for setting WLAs and LAs. In addition, the TMDL watershed model was updated in 2010 to incorporate a more recent land use distribution. Section 3.2.1 describes the results from these models.

- To what extent does watershed loads (referred to as "washoff") translate to reductions in loads delivered to Lake Elsinore and Canyon Lake?
  Section 3.2.2 describes the estimation of loading factors to account for loss of nutrients between washoff areas and inputs to Lake Elsinore and Canyon Lake.

- What is the nutrient load reduction necessary to reduce existing loads down to the WLA for urban and to the LA for septic sources for each MS4 Permittee?
  See Section 3.2.3.

- How much nutrient load reduction has occurred or is expected to occur from external urban and septic sources in the watershed?
  MS4 Permittees have implemented watershed-based BMPs since the adoption of the TMDL in Lake Elsinore and Canyon Lake (see Section 3.3) watersheds. In addition, projected changes in watershed nutrient loads resulting from land use change and application of new WQMP requirements are summarized for Lake Elsinore and Canyon Lake.

- For Lake Elsinore, what in-lake nutrient control strategy is recommended to address remaining load reduction requirements for each MS4 Permittee after accounting for watershed load reduction?
  Section 3.4.1 summarizes in-lake nutrient control recommendations and demonstrates how the selected strategy will provide the necessary load reduction to achieve compliance with the Lake Elsinore WLAs for urban and LAs for septic sources.

- For Canyon Lake, what in-lake management action(s) is recommended to manage lake water quality so that numeric targets for response variables chlorophyll-a and DO can be achieved?
  Section 3.4.2 summarizes proposed in-lake management actions and demonstrates that the selected strategy will provide the necessary reductions in annual average chlorophyll-a and increase in daily average DO to achieve the interim and final chlorophyll-a targets and the interim TMDL numeric target for DO (except for a short period of time during lake turnover), and possibly the final DO target.

- What is the certainty that the CNRP, once implemented, will result in compliance with TMDLs for Lake Elsinore and Canyon Lake?
  Section 3.5 characterizes several important sources of uncertainty, including the role of spatial and temporal variability in nutrient loading as a result of hydrology and modeling assumptions for land use change, watershed and Lake BMP effectiveness, and lake water quality response to both reduced watershed loads and in lake management actions.

The analysis contained herein is based on the TMDL staff report, 2003 TMDL watershed model, 2010 watershed model, and other studies and analyses conducted by various individuals, task forces and agencies. These documents and studies represent the best available data regarding the lakes, their impairments, and potential remediation strategies. However, they are limited by the quality and amount of data that was available at the time of publication. This compliance analysis relies on this older information but also incorporates new data where available. However, this analysis is still an approximation based on best available data. Although this analysis presents existing load data down to the individual Permittee level, the data should be considered order of magnitude estimates of individual responsibility. The CNRP compliance analysis should ultimately be evaluated at the higher level of combined loading and load reductions due to inherent uncertainties in the underlying data sets.

3.2 Watershed Load Assessment

3.2.1 Nutrient Washoff from Urban and Septic Sources

The linkage analysis used to develop the nutrient TMDLs and the subsequent 2010 watershed model update evaluated the role of land cover and failing septic systems in contributing to the wash off of nutrients to receiving waterbodies, such as Salt Creek, San Jacinto River, Perris Valley Channel, and other major tributaries to the lakes. The method used to simulate loads from the watershed involved a continuous simulation of pollutant buildup during dry periods and pollutant washoff as a function of hydrologic response to historical (1990-2009) rainfall records. The Loading Simulation Program C++ (LSPC) tool was used to simulate hydrology and pollutant buildup and washoff using exponential functions. Variables used to simulate hydrology and pollutant buildup and washoff for different land cover types were adjusted within expected ranges to generate results that approximate observed data at six U.S. Geological Survey streamflow gauges and six water quality monitoring sites (Tetra Tech, 2010).

The TMDL was developed based on a frequency-weighted average loading simulated from three hydrologic year types: Wet at 16 percent weight (Water Year [WY] 1997-1998); Dry at 43 percent weight (WY 1999-2000), and Moderate at 41 percent weight (WY 1993-1994). Table 3-2 summarizes, for each MS4 Permittee, the frequency weighted average washoff of nutrients from urban and septic sources based on the 2010 watershed model update.

3.2.2 Estimation of Washoff Loading Factors

Nutrients washed off from source areas are transported to Canyon Lake and Lake Elsinore by a variety of drainage courses. Characteristics of these drainage courses control how much of the washed off pollutant reaches the downstream lakes. Reduction of nutrient loads within conveyance systems, referred to as natural decay in the CNRP, is generally the result of settling of suspended solids and stormwater infiltration within channels and upstream lakes, most notably Mystic Lake. The LSPC model accounted for this decay in the runoff routing simulation. Based on these results loading factors (ratios of lake loading to watershed washoff) were computed for three aggregated analysis zones: Local Lake Elsinore (Figure 3-1, Zone 1); Canyon Lake below Mystic Lake (Figure 3-1, Zones 2-6); and Above Mystic Lake (Figure 3-1, Zones 7-9) (Table 3-3)

Table 3-2. 2010 LSPC Update Simulated Nutrient Washoff from Urban and Septic Sources for each MS4 Permittee in the Local Lake Elsinore, Canyon Lake below Mystic Lake, and Above Mystic Lake Watersheds

MS4 Permittee[1]	TP Washoff (kg/yr)			TN Washoff (kg/yr)		
	Local Lake Elsinore	Canyon Lake below Mystic Lake	Above Mystic Lake	Local Lake Elsinore	Canyon Lake below Mystic Lake	Above Mystic Lake
Beaumont			69			362
Canyon Lake	14	130		78	765	
Hemet		235	187		1,660	1,246
Lake Elsinore	284	44		1,489	222	
Menifee	6	467		17	2,881	
Moreno Valley		1,160	1		7,255	2
Murrieta		1			5	
Perris		388			2,222	
Riverside		37			268	
Riverside County	116	485	697	585	2,374	2,632
San Jacinto		0	201		1	1,294
Wildomar	127	0		639	0	
Septic	13	83	63	176	1109	841
Other Jurisdictions	50	355	103	248	1,877	403
Total	610	3,386	1,339	3,232	20,640	6,902

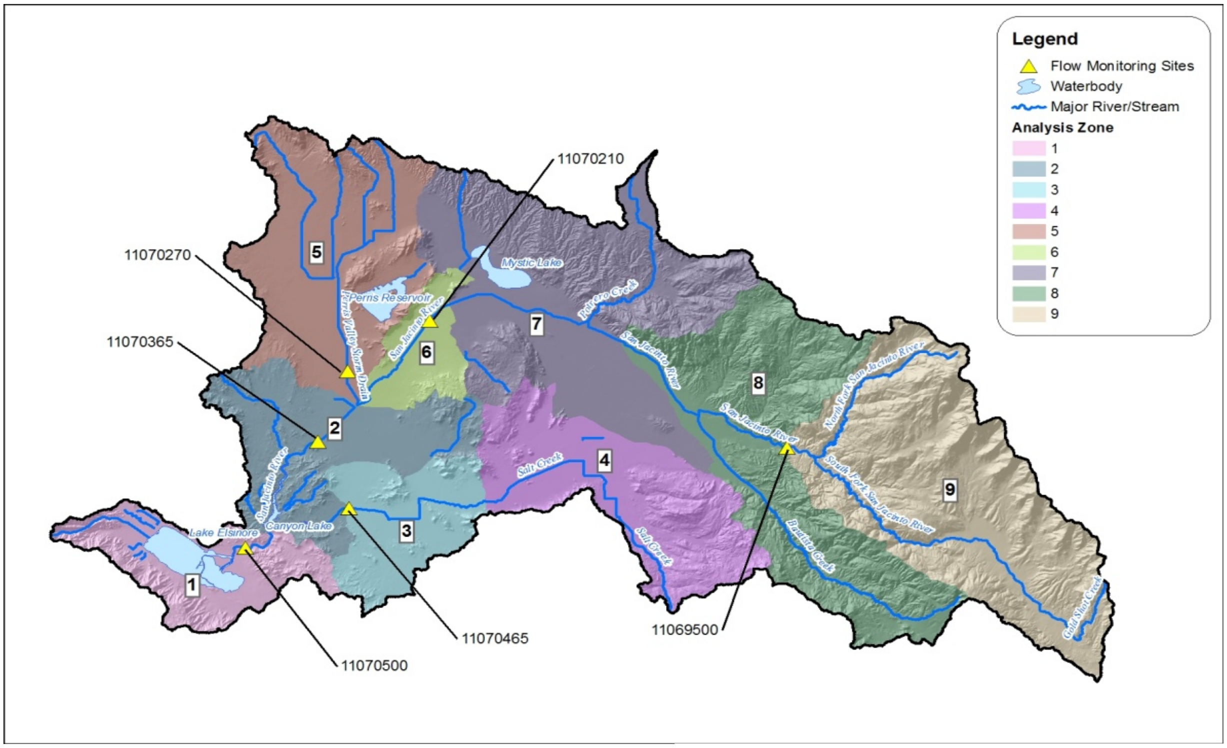


Figure 3-1
San Jacinto River Watershed Analysis Zones

Table 3-3. Estimation of Loading Factors for the Portion of Urban and Septic Watershed Nutrient Washoff that Reaches Lake Elsinore or Canyon Lake

Watershed Analysis Zone	Watershed Washoff[1]		Loads to Lakes[1]		Loading Factor	
	TP (kg/yr)	TN (kg/yr)	TP (kg/yr)	TN (kg/yr)	TP	TN
Local Lake Elsinore (Zone 1)	610	3,232	610	3,232	100%	100%
Canyon Lake below Mystic Lake (Zones 2-6)	3,386	20,640	1,765	12,515	52%	61%
Above Mystic Lake (Zones 7-9)	1,339	6,902	<1	<1	<0.01%	<0.01%

1) Watershed washoff and loads to lakes from urban sources are inclusive of state, federal, and tribal jurisdiction lands

The computed loading factors for the three aggregated zones show that all urban and septic nutrient washoff in the local Lake Elsinore watershed reaches Lake Elsinore. For the Canyon Lake watershed, roughly half of nutrient washoff from urban land areas from the portion of the drainage area that is downstream of Mystic Lake reaches Canyon Lake. For MS4 drainages upstream of Mystic Lake, any loading to Canyon Lake is extremely rare (11 of 240 months) and of small magnitude relative to flow in the Upper San Jacinto River, as has been shown with extensive analysis of flow gauge data and simulation models (http://www.sawpa.org/documents/2010-9-27SanJacintoWatershedModelUpdate.pdf). Thus, it is assumed that nutrients conveyed to Canyon Lake are from drainage areas downstream of Mystic Lake.

These loading factors must be included in any estimate of reduced loading to Lake Elsinore or Canyon Lake from implementing watershed BMPs to avoid double counting reductions that would have been achieved through natural in-stream decay. Therefore, in the Canyon Lake watershed, washoff reductions in MS4 drainage areas do not achieve an equivalent benefit in load reduction to the lakes. For example, watershed BMPs in MS4 drainages in the Canyon Lake watershed below Mystic Lake have to reduce washoff by 1.9 kg TP and 1.6 kg TN to achieve a 1 kg TP or TN reduction in loads to Canyon Lake. This compliance analysis does not evaluate washoff reduction from urban and septic sources above Mystic Lake, where the loading factor is negligible, making washoff reduction ineffective.

3.2.3 Gap Analysis for Urban WLAs and Septic LAs

The load reduction into Lake Elsinore and Canyon Lake necessary to reduce existing load to the urban WLA and septic LA is equal to the difference between existing loads and the allocated loads. For Lake Elsinore, the compliance analysis will show how watershed and in-lake BMPs will achieve the necessary reduction to meet allocation. This gap analysis is completed for Canyon Lake but is not the method used to demonstrate compliance. Instead, the gap analysis for Canyon Lake is used to estimate relative participation in the Canyon Lake in-lake solution that is designed to achieve TMDL numeric response targets for chlorophyll-a and DO.

The relative contribution from each MS4 Permittee drainage area to existing loads into Lake Elsinore and Canyon Lake is used to allocate urban WLAs and septic LAs and determine each Permittees' responsibility for reducing nutrient loads from urban and septic sources. Different approaches are necessary to estimate nutrient loads to the lakes from urban and septic sources, as follows:

- Urban Sources - Washoff from the watershed is modeled for each Permittee. Nutrient washoff from MS4 drainage areas is then translated to an existing load in Lake Elsinore or Canyon Lake by applying the appropriate loading factors depending upon acreage within each aggregated zone.
- Septic Sources - The watershed model simulated total septic loads from each of the three aggregated zones. No assessment of the distribution of septic systems among individual MS4 Permittees was made. The County's GIS shapefile of septic systems at risk provided a means to develop a distribution of existing septic loads for each MS4 Permittee within each aggregated zone.

The urban WLA was divided between the MS4 Permittees based on the relative contribution by each MS4 Permittee to the total urban load (as estimated from the 2010 watershed model). The total septic load to Lake Elsinore and Canyon Lake, as estimated in the 2010 watershed model, is less than the septic LA in the TMDL, hence, there is allowable load in excess of what is attributed to existing septic systems. The reason for this is that analysis to support the development of the 2007 SSMP significantly reduced the estimate of potentially failing septic systems in the San Jacinto River watershed from levels assumed during the TMDL development (Tetra Tech, 2007). The Regional Board required the MS4 Permittees to take the full responsibility of the septic LA. Therefore, it is appropriate to shift the allocation, including credits, to urban MS4 sources.

Tables 3-4 and 3-5 show how the septic LA and excess credits are shifted to MS4 Permittees. For Permittees with septic systems within their jurisdiction, the existing septic load was added to the urban WLA, based on the number of septic systems within 500 feet of a drainage facility within the watershed (see Section 3.3.3 for detailed breakout by jurisdiction). The load allocation in excess of the existing septic load (i.e. credits) was divided between all MS4 Permittees based on relative portion of existing urban load, estimated in the 2010 watershed model update. The final columns of Tables 3-4 and 3-5 compute the gap or load reduction that must be achieved by each MS4 Permittee for both urban and septic sources

For Lake Elsinore, the majority of existing urban and septic load comes from stormwater that flows through Canyon Lake in moderate rainfall years. For purposes of the CNRP compliance analysis, compliance with the Canyon Lake TMDL is assumed to translate to a sufficient reduction in Canyon Lake outflow load to meet the WLA for flows from Canyon Lake to Lake Elsinore. If future data demonstrates that exceedances of WLA for flows from Canyon Lake to Lake Elsinore are still occurring despite compliance with the Canyon Lake TMDL (by achieving response variables chlorophyll-a and DO), then these issues will be addressed through the adaptive implementation process that has been incorporated into this CNRP.

Table 3-4. Gap Analysis for Existing Urban and Septic Total Phosphorus Loading to Lake Elsinore and Canyon Lake for MS4 Permittees (all values in kg/yr)

MS4 Permittee	Existing Load	Urban WLA Septic LA	Load Reduction (Needed) / Credit	Reallocation of Existing Septic Load	Reallocation of Septic Credits	WLA (Urban + Septic)	Remaining Load Reduction (Needed)
Local Lake Elsinore Watershed[1]							
Canyon Lake	14	3	(11)	0	+1	4	(10)
Lake Elsinore	310	65	(246)	+11	+29	104	(206)
Menifee	6	1	(5)	0	+1	2	(4)
Riverside County	119	25	(94)	0	+11	36	(83)
Wildomar	147	31	(116)	+2	+14	47	(100)
Urban Subtotal	597	124	(473)	+13	+56	193	(404)
Septic Total	13	69	56	(13)	(56)	n/a	n/a
Canyon Lake Watershed							
Beaumont	0.0	0	(0)	0	0	0	(0)
Canyon Lake	67	12	(55)	0	+3	15	(52)
Hemet	125	22	(102)	+1	+6	29	(96)
Lake Elsinore	24	4	(20)	0	+1	5	(18)
Menifee	257	46	(211)	+16	+12	74	(183)
Moreno Valley	659	118	(541)	+7	+32	157	(502)
Murrieta	1	0	(1)	0	0	0	(1)
Perris	218	39	(179)	0	+11	50	(169)
Riverside	20	4	(17)	0	+1	5	(16)
Riverside County	337	60	(277)	+32	+16	109	(228)
San Jacinto	0	0	(0)	0	0	0	(0)
Wildomar	0	0	(0)	0	0	0	(0)
Urban Total	1,709	306	(1,403)	+56	+83	445	(1,264)
Septic Total	56	139	83	(56)	(83)		

1) Assumes pass through TP load from Canyon Lake to Lake Elsinore is reduced to the pass through WLA of 2,770 kg if all entities upstream of Canyon Lake reduce loads to their respective WLAs or LAs for the Canyon Lake nutrient TMDL.

Table 3-5. Gap Analysis for Existing Urban and Septic Total Nitrogen Loading to Lake Elsinore and Canyon Lake for MS4 Permittees (all values in kg/yr)

MS4 Permittee	Existing Load	Urban WLA Septic LA	Load Reduction (Needed) / Credit	Reallocation of Existing Septic Load	Reallocation of Septic Credits	WLA (Urban + Septic)	Remaining Load Reduction (Needed)
Local Lake Elsinore Watershed							
Canyon Lake	78	9	(69)	0	+11	20	(58)
Lake Elsinore	1,615	184	(1,430)	+143	+228	555	(1,059)
Menifee	17	2	(15)	0	+2	4	(13)
Riverside County	600	68	(531)	0	+85	153	(446)
Wildomar	747	85	(662)	+33	+106	224	(523)
Urban Subtotal	3,056	349	(2,707)	+176	+432	957	(2,099)
Septic Total	176	608	432	(176)	(432)		
Canyon Lake Watershed							
Beaumont	0.0	0	(0)	0	0	0	(0)
Canyon Lake	459	156	(302)	0	+157	313	(145)
Hemet	1,011	344	(666)	+9	+346	700	(311)
Lake Elsinore	139	47	(91)	0	+48	95	(44)
Menifee	1,825	622	(1,203)	+241	+625	1,488	(337)
Moreno Valley	4,694	1,600	(3,094)	+112	+1,608	3,320	(1,374)
Murrieta	7	2	(4)	0	+2	5	(2)
Perris	1,437	490	(947)	+1	+492	983	(453)
Riverside	165	56	(109)	0	+57	113	(52)
Riverside County	1,925	656	(1,269)	+491	+660	1,807	(119)
San Jacinto	1	0	(1)	0	0	1	(0)
Wildomar	0	0	(0)	0	0	0	(0)
Urban Total	11,661	3,974	(7,687)	+854	+3,996	8,824	(2,837)
Septic Total	854	4,850	3,996	(854)	(3,996)		

1) Assumes pass through TN load from Canyon Lake to Lake Elsinore is reduced to the pass through WLA of 20,774 kg if all entities upstream of Canyon Lake reduce loads to their respective WLAs or LAs for the Canyon Lake nutrient TMDL.

3.3 Load Reduction from Watershed BMPs

Since TMDL adoption, MS4 program implementation has resulted in reductions in nutrient washoff from MS4 drainage areas. For stormwater program activities involving changes to human behavior, the nutrient washoff reduction benefit was not incorporated into the assessment of expected load reduction due to uncertainty in effectiveness (see Section 2.2.1); however, rough estimates were developed and used to quantify a margin of safety (MOS) for TMDL compliance (see Section 3.5.3). Watershed BMPs that provide a quantifiable reduction of nutrient washoff loads are detailed in the following sections.

3.3.1 Street Sweeping and MS4 Debris Removal

Street sweeping and MS4 facility debris removal activities reduce a significant source of nutrients in urban environments. Quantifying these reductions required assessment of sediment and debris mass removal data and development of an analysis to convert tonnage of sediment and debris collected to reductions in washoff loads. The MS4 Permittees provided street sweeping and MS4 debris removal data for the reporting period from 2005 to 2010 (see Table D-2, Annual Street Sweeping Summary). This data was the basis for quantifying nutrient washoff reduction for the CNRP compliance analysis.

A continuous simulation analysis was developed to compute sediment and debris accumulation prior to each storm event(buildup) and transport to downstream waterbodies during each storm event(washoff) (Wolosoff et. al., 2010). The consecutive sequence of storm events provided a basis to perform a simulation of pollutant buildup during inter-event periods and washoff as a function of event runoff. Historical daily rainfall data for the Lake Elsinore NCDC meteorological station was used to estimate average runoff depth from a typical urban street, assuming a runoff coefficient of 0.9 for the impervious drainage area (i.e. runoff depth is 90 percent of rainfall depth to allow for depression storage and other initial abstractions).

The buildup/washoff model determined a long-term average washoff ratio (W_r) of roughly 50 percent. This is the portion of collected sediment and debris that would have otherwise been washed off to MS4s and receiving waterbodies. Translating avoided sediment and debris washoff into a potential reduction in nutrient loads requires an estimate of expected concentrations in typical street sediment and debris (C_s), measured as kg/metric ton, within MS4s for TP and TN. The City of San Diego Targeted Aggressive Street Sweeping Pilot Program, completed in 2011 measured concentrations of nutrients in sediment and debris on streets and found approximately 0.3 kg/metric ton for TP and 1.0 kg/metric ton for TN (City of San Diego, 2011). These values are comparable to nutrient concentration data reported by Pitt et al. (1973) from sites in Wisconsin (0.07-0.6 kg/metric ton TP and 0.5-1.9 kg/metric ton TN), Walch, 2006 from sites in Delaware (0.3 kg/metric ton TP and 0.7 kg/metric ton TN), and Breault et. al., 2005 from sites in Massachusetts (0.3-0.16 kg/metric ton TP). Therefore, for every metric ton of sediment and debris removed (M_{swept}), 0.15 kg of TP and 0.5 kg of TN is reduced from washoff, as;

$$\mathbf{W_{BMP} = M_{swept} * W_r * C_s}$$

Table 3-6 presents the baseline mean quantity of debris removed from street sweeping activities and MS4 facilities cleaning, between the 2005 and 2010 reporting years, within the San Jacinto River watershed and the estimated nutrient washoff reduction based on the method described above.

Table 3-6. Estimated Total Phosphorus and Total Nitrogen Annual Load Reduction (kg/yr) from Street Sweeping and MS4 Debris Removal

Jurisdiction	Debris Removal Average [1] (metric tons/yr)	Street Sweeping Average Removal [1] (metric tons/yr)	Baseline Metric Tons/yr (2005-2010)	TP Removed (kg/yr)	TN Removed (kg/yr)
Local Lake Elsinore					
Canyon Lake	1	8	8	0	0
Lake Elsinore	0	350	350	47	157
Menifee	24	5	29	0	0
Riverside County	182	538	720	6	20
Wildomar	0	25	25	4	13
Total				57	189
Canyon Lake					
Beaumont	23	23	45	0	0
Canyon Lake	1	8	8	1	4
Hemet	2	1,080	1,082	114	380
Lake Elsinore	0	350	350	6	19
Menifee	36	0	36	5	18
Moreno Valley[2]	18	893	911	132	442
Murrieta[2]	24	5	29	4	14
Perris	66	506	573	86	286
Riverside	0	29	29	4	14
Riverside County	182	538	720	52	175
San Jacinto	6	128	134	0	0
Wildomar	0	25	25	0	0
Total	359	3,584	3,942	406	1,352

1) Tonnage data is based on an extrapolation for catch basins cleaned, sweepers filled, and other metrics. Permittees are evaluating alternatives to more directly measure the mass removed from streets and MS4 facilities. Values are less than total reported debris removal for some Permittees (shown in Table D-2) due to discounting sweeping performed upstream of Mystic Lake according to proportion of road miles upstream of Mystic Lake.

2) Permittees reported MS4 debris data as volumetric measurements. Conversion to tonnage assumed debris density of 1.5 g/cm^3.

3.3.2 Structural Post Construction BMPs

MS4 Permittees within the San Jacinto River Watershed first required new development projects to establish post-construction stormwater BMPs that provide nutrient load reduction benefits as part of the San Jacinto Watershed Construction Permit requirements (Regional Board Permit No. CAG 618005, Order 01-34). These Permit requirements were effective from 2002 until the adoption of the Water Quality Management Plan for New Developments and Redevelopments pursuant to the third-term Riverside County MS4 Permit in 2005. Structural post-construction BMPs completed as a result of these requirements were not accounted for in the 2010 watershed model update. The MS4 Permittees have researched historic development and provided data for structural post-construction BMPs constructed within the San Jacinto River watershed and they are now accounted for in this compliance analysis (see Attachment D, Table D-6).

The 2010 watershed model update provides estimated pollutant loading rates or export coefficients (L_{EC}) for TP and TN of 0.08 kg/acre/yr and 0.42 kg/acre/yr, respectively. These loading rates do not account for inclusion of structural BMPs in WQMP projects. Reduction in washoff due to implementation of WQMP projects is estimated by reducing the modeled loading rate for new urban development since adoption of the TMDL. Two factors are applied, including:

- Average annual percent of runoff capture ($V_{capture}$) - Since BMPs in Riverside County are designed to meet MS4 Permit water quality volume criteria (Section VII.D.4(a)), constructed BMPs were assumed to treat approximately 80 percent of the volume of long-term average annual storm water runoff.

- Pollutant removal efficiency (R_{eff}) - BMP removal efficiency for infiltration is assumed to be 100 percent. For BMPs that treat and release runoff, average stormwater BMP effluent concentrations reported in the international BMPs database were compared with MS4 outfall concentrations at NPDES monitoring locations in the San Jacinto River watershed to approximate pollutant removal efficiency (ASCE, 2010). Results are summarized below:

  - Infiltration – 100 percent removal for the Vcapture
  - Extended detention – TP 75 percent; TN 24 percent
  - Hydrodynamic separators – TP 33 percent; TN 13 percent
  - Vegetated swale - TP 47 percent; TN 0 percent
  - Media filter – TP 69 percent; TN 0 percent

For each jurisdiction in this analysis, the area of new development draining to structural stormwater BMPs in acres (DA_{WQMP}), provided by the MS4 Permittees, was used to determine the TP and TN washoff reduction as follows:

$$\mathbf{W_{reduction} = DA_{WQMP} * L_{EC} * V_{capture\%} * R_{eff\%}}$$

Table 3-7 shows the estimated annual nutrient washoff reduction for each MS4 Permittee associated with implementation of structural BMPs in WQMP projects. It should be noted that not all Permittees were able to track deployment of BMPs constructed under the San Jacinto construction permit. Only those BMPs that could be verified were included in Table 3-7.

3.3.3 Septic System Management

Each Permittee with septic systems within their jurisdiction will implement the System Management Plan (SSMP) aimed to reduce nutrient washoff from failing septic systems to MS4s in the San Jacinto River watershed. The SSMP includes proposed activities such as enhancing performance requirements for new systems, examining existing systems near impaired waters to determine potential impacts, and repairing or replacing existing systems that may threaten valuable water resources.

Table 3-7. WQMP Project BMPs and Nutrients Load Reduction (kg/yr)

Jurisdiction[1]	BMP Treatment Area (acres)					TP Washoff Reduction (kg/yr)	TN Washoff Reduction (kg/yr)
	Infiltration	Extended Detention	Hydrodynamic Separator	Vegetated Swale	Media Filter		
Local Lake Elsinore Watershed							
Lake Elsinore	707	1995		9		145	395
Canyon Lake Watershed							
Hemet	54	44		10		6	22
Menifee		75				4	6
Moreno Valley	159	1,032	8	21		61	136
Murrieta	8.5					1	3
Perris	513	768	819	114	18	92	267
City of Riverside[2]		511				25	41
County of Riverside		25				1	2
Subtotal	735	2,455	827	145	18	450	476

1) Recent WQMPs assumed to be entirely within the local Lake Elsinore watershed portion of the City of Lake Elsinore's jurisdictional area. For Cities of Canyon Lake, Menifee, and Wildomar, and County of Riverside, recent WQMPs are assumed to be entirely within the Canyon Lake watershed portion of their respective jurisdictional areas

2) Extended detention basins located in March Joint Powers Authority treats all runoff from city of Riverside

The SSMP development employed a GIS screening approach to approximate properties with potentially failing septic systems based on distance from sewer lines and proximity to watercourses, assuming that 10 percent of properties are uninhabited and a 30 percent failure rate for properties with operating septic systems. The current condition washoff of nutrients attributed to septic sources was simulated in the 2010 watershed model update, and is used herein to estimate the load reduction benefits from correcting failing septic systems or improving sewering projects. Modeled loads from septic systems divided into the number of potentially failing septic systems, provides an approximate nutrient load reduction that could be achieved for each septic system corrected by the Permittees (Table 3-8).

Table 3-8. Estimation of Failing Septic System Washoff Rates in Local Lake Elsinore and Canyon Lake Watersheds based on 2010 Watershed Model Update

Variable	Local Lake Elsinore	Canyon Lake below Mystic Lake
Properties w/ septic systems at risk	106	2,204
Properties w/ potentially failing septic	29	595
Modeled TN washoff (kg/yr)	176	854
Modeled TP washoff (kg/yr)	13	56
TN Washoff Rate (kg/failing septic/yr)	6.1	1.4
TP Washoff Rate (kg/failing septic/yr)	0.5	0.1

1) Potentially failing systems assumes 10 percent of properties with septic system at risk are uninhabited and 30 percent of inhabited properties with a septic system at risk are failing

The estimated washoff rates in Table 3-8 are used to approximate the washoff reduction that could be achieved from implementation of the SSMP and sewering projects, assuming either septic system repair for 25 percent of potentially failing septic systems or complete reduction of all septic washoff in areas planned for sewering projects (Table 3-9).

Table 3-9. Estimated Washoff Reduction from SSMP Implementation and Sewering Projects in San Jacinto River Watershed

Jurisdiction	Number of Septic Systems	Failing Septic Systems Managed	TP Washoff Reduction (kg/yr)	TN Washoff Reduction (kg/yr)
Local Lake Elsinore Watershed				
Lake Elsinore	86	6	2.7	36.9
Wildomar	20	2	0.9	12.3
Total	106	8	3.6	49.2
Canyon Lake Watershed				
Canyon Lake	54	4	0.4	5.7
Hemet	20	2	0.2	2.9
Menifee	544	37	3.5	53.1
Moreno Valley	253	18	1.7	25.8
Murrieta	1	0	0.1	1.4
Perris (Enchanted	223	61	5.7	87.5
Riverside County	1,109	75	7.1	107.6
Total	2,204	198	18.6	284.2

In the City of Perris, the Enchanted Heights neighborhood has approximately 223 dwelling units on septic systems. Using the 2010 Model's 10 percent vacancy consideration and a 30 percent septic system failing rate, the number of potentially failing septic systems that would benefit from sewering is 61. In 2011, construction began on a three-year sewer system project to replace the existing septic systems. Converting the Enchanted Heights neighborhood to a wastewater treatment system would provide a conservative nutrient reduction of approximately 6 kg/year of TP and 88 kg/year of TN.

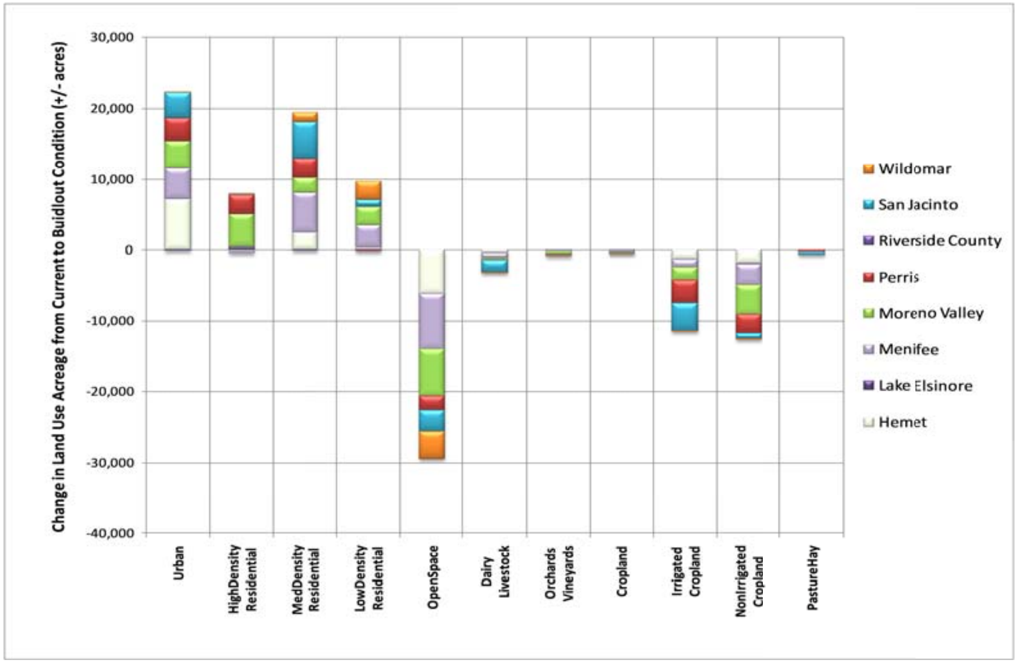
In 2008, the Quail Valley development was incorporated into the City of Menifee. The majority of homes in the development are served by septic systems. There are 1,390 existing dwelling units in Quail Valley of which 1,057 are located in areas scripted to be converted from septic to the regional sewer treatment facility. This potential project would increase the CNRP estimate of septic load reduction from the Quail Valley area if it is implemented in the future; however, it is not included in the load reductions shown in Table 3-9.

3.3.4 Future Low Impact Urban Development

The San Jacinto watershed has significant urban growth potential, which over the long-term will alter the distribution of land use. Since nutrient loading rates or export coefficients vary for different land uses, loading to Lake Elsinore and Canyon Lake will change. Depending upon the pre-developed land use, loads could increase (e.g. converting from open space land use) or decrease (e.g. converting from CAFO land use). Land use types have an associated nutrient loading rate or export coefficient, which contributes to non-point source loading within a watershed. For example, in the Canyon Lake below Mystic Lake watershed, the modeled TP export coefficient from urban land use is 0.08 kg/acre/year, while the forested land use TP export coefficient is 0.02 kg/acre/year.

Current land use was compared to long-term general plan land use projections provided by each Permittee. Figure 3-2 shows the change in land use projected for each Permittee from current to buildout conditions. Only jurisdiction areas in the local Lake Elsinore and Canyon Lake below Mystic Lake watersheds are included in this assessment since the majority of washoff from above Mystic Lake is retained within Mystic Lake. Urban growth potential in the San Jacinto River watershed is an approximate even split between conversion of agricultural lands and development of open spaces (Figure

3-2). For Permittees that are largely built out, washoff reductions may be achieved through re-development of existing land uses with implementation of new LID requirements in WQMPs. However this was not included in the quantification for the CNRP compliance analysis. Tables 3-10 and 3-11 provide current and buildout land use distributions for each of the MS4 Permittees within the local Lake Elsinore and Canyon Lake below Mystic Lake watersheds.



igure 3-2
General

Table 3-10. Current Land Use for MS4 Permittees in the Local Lake Elsinore and Canyon Lake below Mystic Lake Watersheds

Jurisdiction	Acres	Urban	High Density Residential	Med Density Residential	Low Density Residential	Open Space	Forested	Water	Dairy / Livestock	Orchards / Vineyards	Cropland	Irrigated Cropland	Non Irrigated Cropland	Pasture / Hay
Local Lake Elsinore														
Canyon Lake	316	29		102	3	81	102							
Lake Elsinore	13,376	1,525	145	1,910	327	259	6,026	3,095		18	3	0	69	
Menifee	414				125		273				13	3		
Riverside County	10,574	155	8	787	1,000	57	8,334	110	42	14	24	31	12	
Wildomar	5,074	480		531	1,345	31	2,532		7	32	2	32	84	
Subtotal	29,754	2,188	153	3,330	2,799	428	17,267	3,205	48	63	43	66	164	0
Canyon Lake Watershed (below Mystic Lake)														
Canyon Lake	2,653	46	17	1,128	63	61	853	470	9				6	
Hemet	13,020	1,916	414	2,973	105	930	3,537	191	181	3	20	867	1,883	
Lake Elsinore	1,573	124		254	11	13	1,171							
Menifee	28,580	3,194	292	4,675	3,413	1,594	6,412	640	746	210	199	1,232	5,971	
Moreno Valley	27,009	3,316	339	8,512	2,224	1,004	6,605	331	125	236	56	1,814	2,447	
Murrieta	375	75	18	235	9	26								12
Perris	20,277	2,925	154	2,056	1,055	2,151	4,917	470	50	144	49	3,269	2,710	327
Riverside	511	39		459		13								
Riverside County	105,128	4,655	174	1,571	10,591	6,600	61,047	3,215	2,636	705	337	7,960	5,637	
San Jacinto	223	30			7	14	60	27	15			34	35	
Wildomar	7	0					7							
Subtotal	199,496	16,396	1,404	21,833	17,487	12,387	84,656	5,356	3,771	1,298	661	15,178	18,742	327

Table 3-11. General Plan Buildout Land Use for MS4 Permittees in the Local Lake Elsinore and Canyon Lake below Mystic Lake Watersheds

Jurisdiction	Acres	Urban	High Density Residential	Med Density Residential	Low Density Residential	Open Space	Forested	Water	Dairy / Livestock	Orchards / Vineyards	Cropland	Irrigated Cropland	Non Irrigated Cropland	Pasture / Hay
Local Lake Elsinore														
Canyon Lake	316	29		102	3	81	102							
Lake Elsinore	13,376	1409	511	1823	215	2226	4423	2770	0	0	0	0	0	0
Menifee	414	110	2	150	99	46	7	0	1	0	0	0	0	0
Riverside County	10,574	196	9	1,003	1,203	31	7,900	110	42	14	24	31	12	0
Wildomar	5,074	376	80	1402	3048	168	0	0	0	0	0	0	0	0
Subtotal	29,754	2,119	602	4,480	4,567	2,551	12,432	2,879	43	14	24	31	12	0
Canyon Lake Watershed (below Mystic Lake)														
Canyon Lake	2,653	46	17	1,128	63	61	853	470	9				6	
Hemet	13,020	7,014	414	4,763	638	0	0	191						
Lake Elsinore	1,573	209	76	270	32	330	656	0						
Menifee	28,580	7,503	292	10,104	6,750		70	640	79			79	3,062	
Moreno Valley	27,009	5,966	4,180	8,823	4,009	3,701	0	331						
Murrieta	375	75	18	235	9	26								12
Perris	20,277	6,213	2,791	4,729	1,051	3,643	1,380	470						
Riverside	511	39		459		13								
Riverside County	105,128	9,007	255	12,145	32,786	5,552	37,309	3,215	1,272	705	337	1,272	1,272	0
San Jacinto	223	30			7	14	60	27	15			34	35	
Wildomar	7	0					7	0						
Subtotal	199,496	36,180	8,038	42,625	45,353	13,321	40,381	5,356	1,384	705	338	1,385	4,428	0

For each Permittee in each watershed analysis zone, area-weighted averages of land use specific TP and TN loading rates were computed for current landuse and projections at buildout as well as estimates of urban growth by the year 2020. The Riverside County economic forecast developed by Caltrans provided a means to project the portion of urban growth that will occur by 2020, when compliance with the LE/CL nutrient TMDL must be achieved (http://www.dot.ca.gov/hq/tpp/offices/eab/socio_economic_files/2011/Riverside.pdf). Figure 3-3 shows the projected rate of growth over time from 2010 until the projected buildout date of 2035. This growth rate was used to compute dynamic land use based loading between 2010 and 2020 for TP and TN in Canyon Lake below Mystic Lake (Figures 3-4 and 3-5) and local Lake Elsinore (Figures 3-6 and 3-7) watersheds. The impact of urbanization is not as significant in the Lake Elsinore watershed.

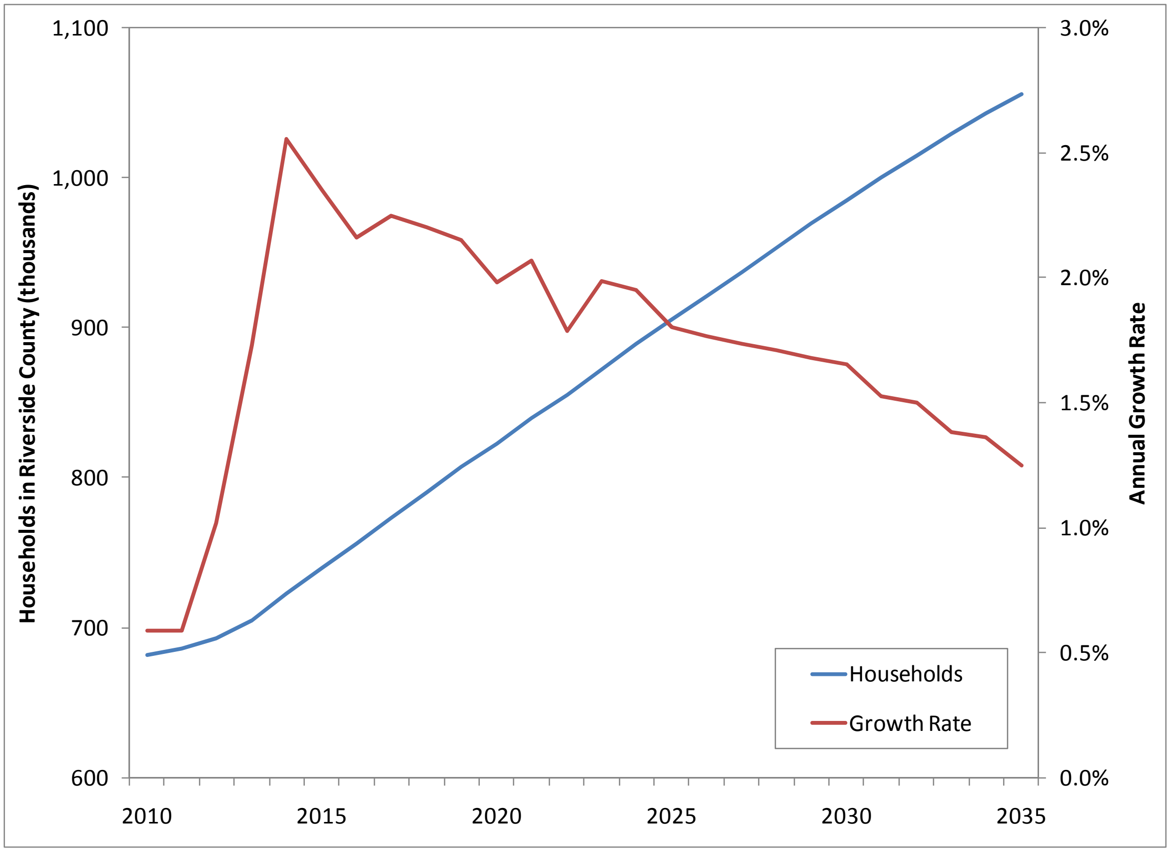


Figure 3-3
Projected Growth Rate for Urban Development in Riverside County (from Caltrans, 2011)

Also accounted for in these estimates of loading rate change are assumed reductions to account for LID requirements in WQMPs. LID BMPs will reduce nutrient washoff rate below those currently assumed for urban land uses in the watershed model. For planning purposes, 40 percent of future WQMPs are assumed to provide complete on-site retention of the water quality volume. For the remaining 60 percent of future WQMPs, it was assumed that biotreatment of the water quality volume would be 75 and 24 percent effective in removing TP and TN, respectively.

The expected change in nutrient washoff from urban growth and future LID is summarized for each Permittee in Table 3-12. Figure 3-8 shows the difference between current and 2020 weighted average loading rates for TP and TN for jurisdictions with significant growth potential (positive = net increasing load; negative = net load reduction).

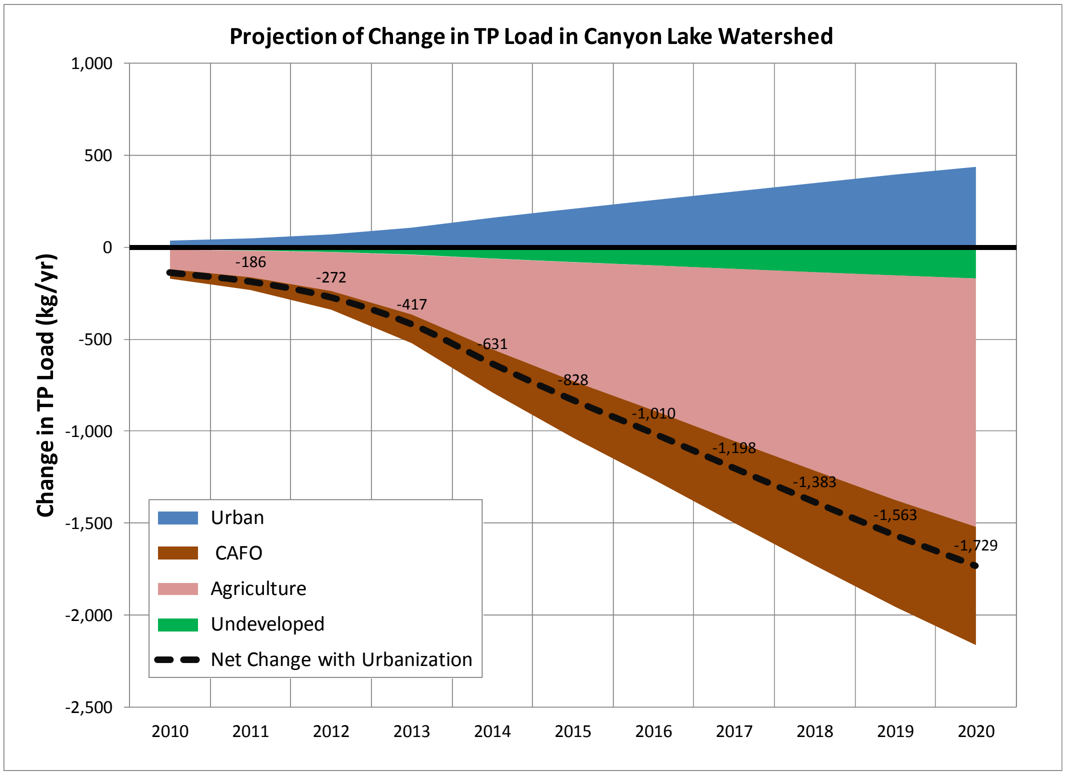


Figure 3-4

Projected TP Load from Urban, Agriculture, CAFO, and Undeveloped Lands in Canyon Lake Watershed

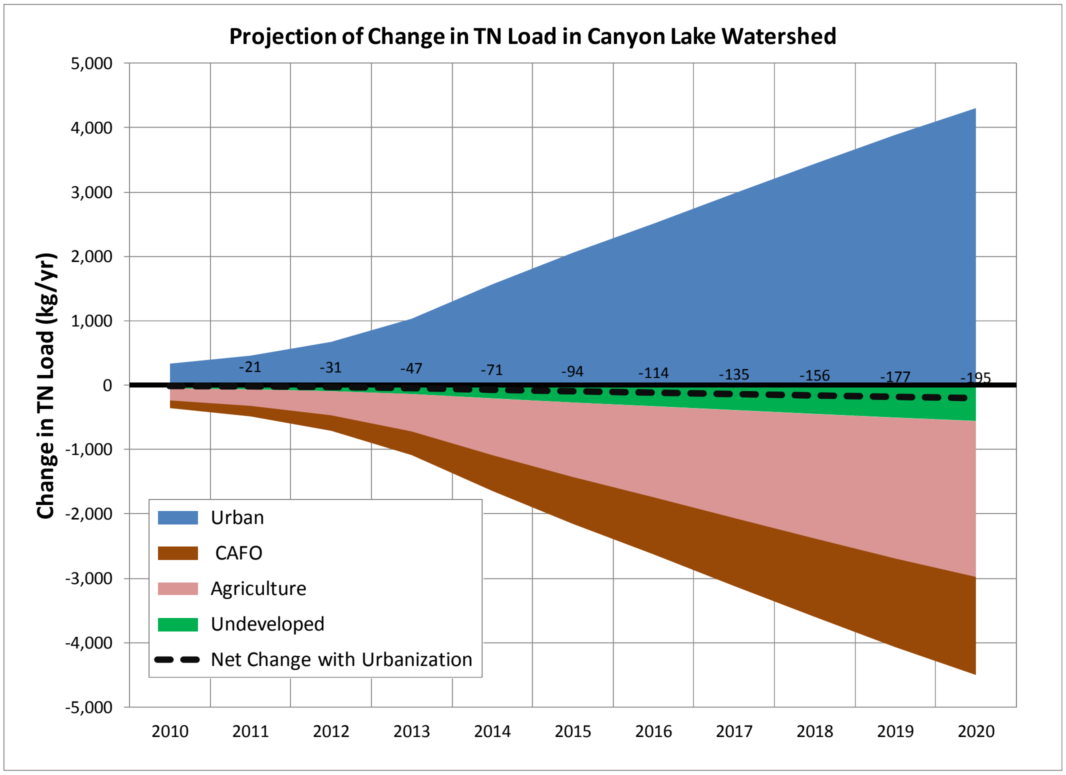


Figure 3-5

Projected TN Load from Urban, Agriculture, CAFO, and Undeveloped Lands in Canyon Lake Watershed

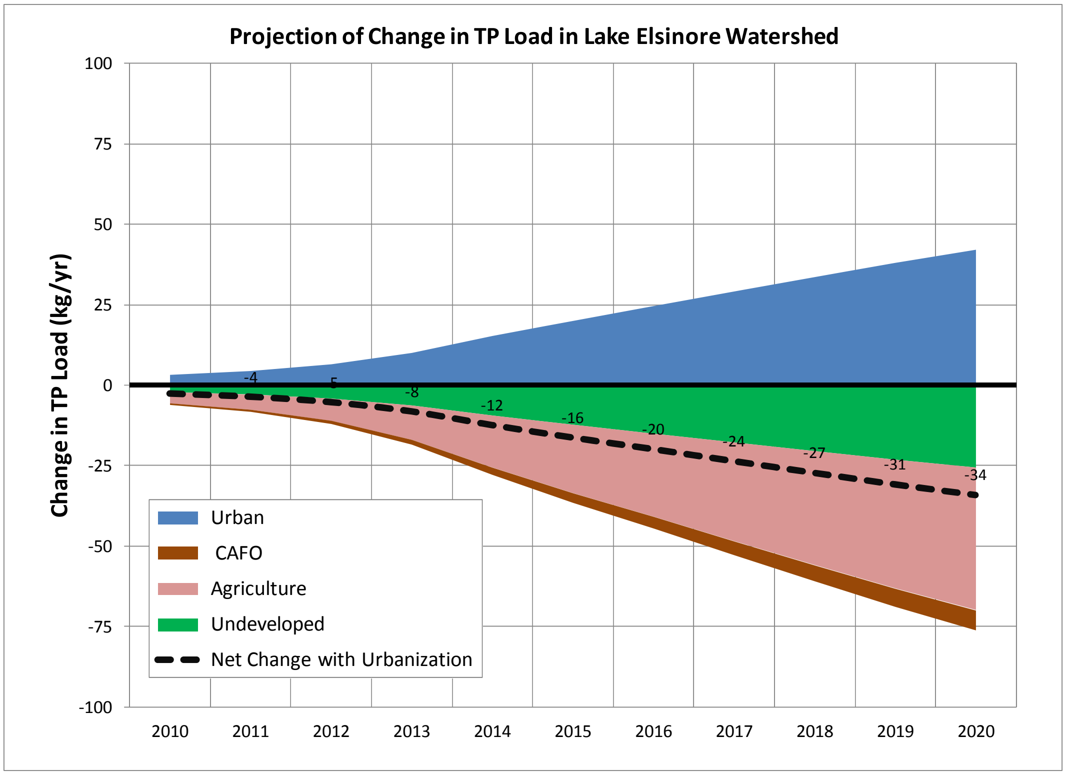


Figure 3-6

Projected TP Load from Urban, Agriculture, CAFO, and Undeveloped Lands in Lake Elsinore Watershed

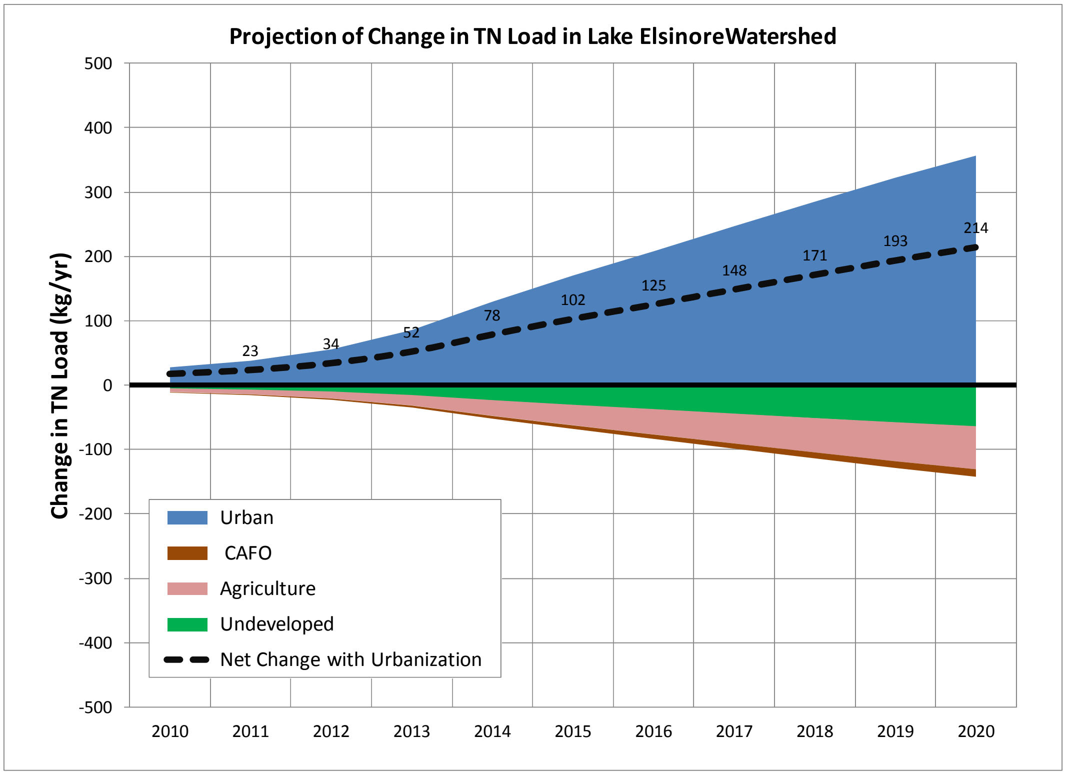


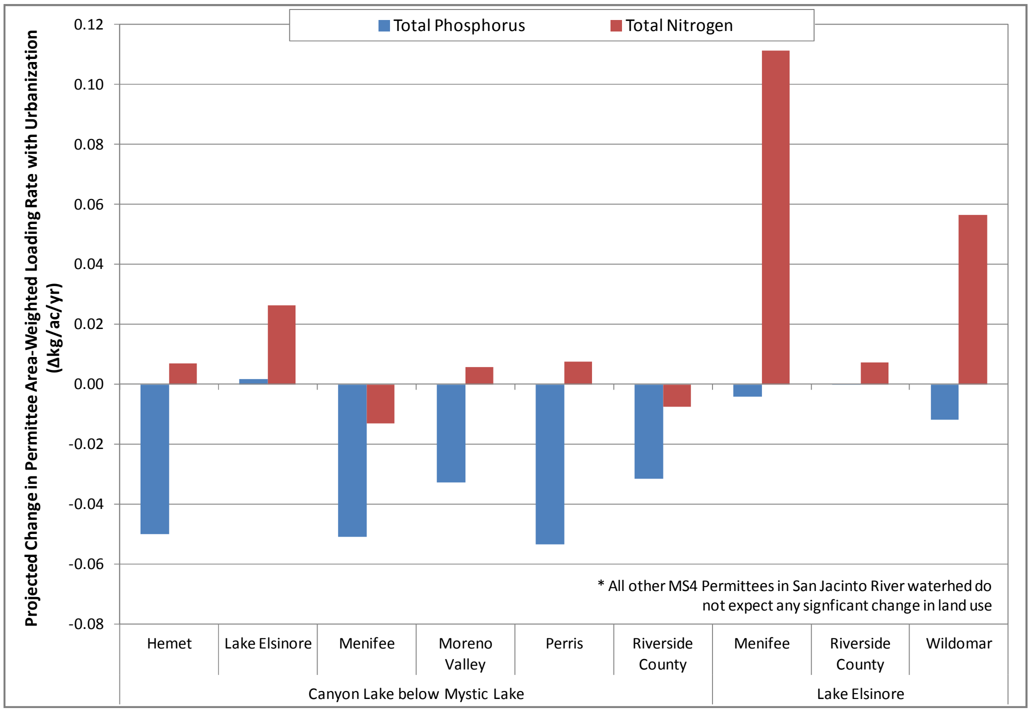
Figure 3-7

Projected TN Load from Urban, Agriculture, CAFO, and Undeveloped Lands in Lake Elsinore Watershed

Table 3-12. Change in Washoff as a Result of Urban Development for MS4 Permittees based on Projections of Buildout Land Use Distribution

MS4 Permittee	Jurisdictional Area (acres)	Current Loading Rate (kg/ac/yr)		Projected Buildout Loading Rate (kg/ac/yr)		Washoff Reduction / (Increase) (kg/yr)	
		TP	TN	TP	TN	TP	TN
Local Lake Elsinore Watershed							
Canyon Lake	316	0.06	0.25	0.06	0.25	0	(0)
Lake Elsinore	13,376	0.04	0.17	0.04	0.18	16	(63)
Menifee	414	0.06	0.16	0.05	0.27	2	(46)
Riverside County	10,574	0.05	0.15	0.05	0.16	(2)	(78)
Wildomar	5,074	0.07	0.23	0.05	0.29	60	(287)
Total	29,754					75	(474)
Canyon Lake Watershed [1]							
Canyon Lake	2,653	0.05	0.28	0.05	0.28	0	0
Hemet	13,020	0.10	0.31	0.05	0.32	652	(90)
Lake Elsinore	1,573	0.03	0.15	0.04	0.18	(3)	(42)
Menifee	28,580	0.12	0.32	0.07	0.31	1450	369
Moreno Valley	27,010	0.09	0.32	0.06	0.33	881	(154)
Murrieta	375	0.08	0.46	0.08	0.46	0	0
Perris	20,277	0.09	0.24	0.04	0.25	1083	(152)
Riverside	511	0.09	0.53	0.09	0.53	0	0
Riverside County	105,127	0.08	0.18	0.05	0.17	3317	792
San Jacinto	223	0.16	0.32	0.16	0.32	0	0
Wildomar	7	0.02	0.05	0.02	0.05	0	0
Total	199,496					7380	722

1) Only areas below Mystic Lake were evaluated for change in watershed washoff as a result of future urban development incorporating LID requirements in WQMPS



* All other MS4 Permittees in San Jacinto River waterhed do not expect any signficant change in land use

Figure 3-8

Change in Land Use Area Weighted Loading Rates from 2010 to 2020 for Permittees with Urban Growth Potential in the San Jacinto River Watershed

3.3.5 Watershed BMP Summary

Table 3-13 provides a summary of the estimated reduction of TP and TN washoff from MS4 drainage areas in the local Lake Elsinore and Canyon Lake watersheds. Washoff reductions include accrued benefits from MS4 program implementation since the adoption of the TMDL as well as future projections of program implementation. Future development in the watershed generates the greatest reduction in TP loading for the Canyon Lake watershed, due to the combined benefit of lower TP washoff rates for urban land uses (as compared to agricultural land uses) and the additional reduction in urban washoff from new WQMP requirements. Conversely, future development is expected to result in a net *increase* in loading for TN in Canyon Lake and TN and TP in the Lake Elsinore watershed. Increased washoff of nutrients occurs when expected benefits of new LID requirements for new development do not offset higher washoff rates for urban land use relative to pre-developed condition. For example, open space/forest have lower TP and TN washoff rates and some agricultural land uses have lower TN washoff rates relative to some urban land use categories.

Table 3-13. Summary of Expected Watershed Nutrient Washoff Reduction from Implementation of MS4 Stormwater Programs for Lake Elsinore and Canyon Lake Watersheds

MS4 Permittee	Street Sweeping and Debris Removal (kg/yr)		Existing WQMP BMPs (kg/yr)		Septic System Management / Sewering (kg/yr)[1]		2010-2020 Average Future Urban LID (kg/yr) [2]		Total Watershed Washoff Reduction (kg/yr)	
	TP	TN	TP	TN	TP	TN	TP	TN	TP	TN
Local Lake Elsinore Watershed										
Canyon Lake	0	0					0	(0)	0	0
Lake Elsinore	47	157	145	395	3	37	4	(14)	198	575
Menifee	0	0					0	(10)	0	-10
Riverside County	6	20					(0)	(17)	5	3
Wildomar	4	13			1	12	13	(63)	18	-38
Total	57	189	145	395	4	49	17	(104)	222	529
Canyon Lake Watershed below Mystic Lake										
Canyon Lake	1	4			0.4	6	0	0	2	10
Hemet	114	380	9	22	0.2	3	143	(20)	267	385
Lake Elsinore	6	19					(1)	(9)	5	9
Menifee	5	18	4	6	3.5	53	319	81	331	158
Moreno Valley	132	442	70	136	1.7	26	194	(34)	398	570
Murrieta	4	14	1	3	0.1	1	0	0	5	18
Perris	86	286	341	267	5.7	88	238	(33)	671	607
Riverside	4	14	25	41			0	0	29	56
Riverside County	52	175	1	2	7.1	108	730	174	790	458
Total	406	1352	450	476	19	284	1,624	159	2,500	2,271

1) Loading factor not required in accounting for failing septic system reductions in lake loads. For all other watershed BMPs, loading factor must be included in determining resulting reduction in loads to lakes

2) Negative values indicate an increase of watershed nutrient washoff. Change in loads as a result of urbanization is representative of roughly 22 percent of buildout growth forecasted to occur by 2015.

Reductions of watershed nutrient washoff translate to reductions in nutrient load to Canyon Lake and Lake Elsinore based on the appropriate loading factors in Table 3-3. Table 3-14 shows the remaining load reduction requirement after accounting for watershed washoff reductions. For the Lake Elsinore TMDL, the MS4 Permittees will meet these load reductions through implementation of in-lake remediation projects. For the Canyon Lake TMDL, the remaining load reductions are used for allocating responsibility between the upstream MS4 Permittees. The values reported in Table 3-14 are based on a projection of 22 percent of urban growth occurring by 2015 in the San Jacinto River watershed. This closely approximates the 2010-2020 average and is therefore consistent with the averaging period for WLAs included in the TMDL. Figure 3-9 shows the projected trend in load reduction needs from in-lake remediation strategies in both Canyon Lake and Lake Elsinore. The changes in load reduction requirements over time show an increasing need to reduce TN and a decreasing need to reduce TP. This is largely due to higher TN loading rates for residential land uses in the 2010 watershed model.

Table 3-14. Calculated Load Reduction Requirements to be Achieved with In-Lake Remediation Projects

MS4 Permittee	Total Load Reduction Requirement (kg/yr)		Watershed Load Reduction / (Debit) [1] kg/yr)		In-Lake BMP Load Reduction Requirement (kg/yr) [2]	
	TP	TN	TP	TN	TP	TN
Local Lake Elsinore Watershed [2]						
Canyon Lake	10	58	0	0	10	58
Lake Elsinore[3]	217	1,202	198	575	19	627
Menifee	4	13	0	(10)	4	23
Riverside County	83	446	5	3	78	443
Wildomar	103	556	18	(38)	85	594
Total	417	2,275	222	529	195	1745
Canyon Lake Watershed						
Canyon Lake	52	145	1	8	51	137
Hemet	96	320	139	232	(43)	88
Lake Elsinore	18	44	3	6	15	38
Menifee	199	578	174	116	25	462
Moreno Valley	509	1,486	208	352	301	1,134
Murrieta	1	2	3	17	(2)	(15)
Perris	169	455	352	399	(183)	56
Riverside	16	52	15	33	1	19
Riverside County	261	609	414	318	(153)	291
Total	1,320	3,691	1308	1477	11	2,209

1) Load reduction from watershed takes into account a washoff loading factor, whereby only a portion of the expected washoff reduction in Table 3-13 is translated to a reduction in loading to Lake Elsinore and Canyon Lake. Load reductions for septic system management and sewering projects are not subject to this loading factor because the watershed model simulated failing septic systems as direct points sources to Lake Elsinore and Canyon Lake.

2) Does not include baseline sediment nutrient flux reduction necessary to create assimilative capacity for phosphorus in Lake Elsinore, allowing for TMDL WLAs above zero.

3) The City of Lake Elsinore currently participates in, or operates, several in-lake watershed programs that exceed their current load reduction obligations shown above. These programs include aeration, fishery management and lake-water addition

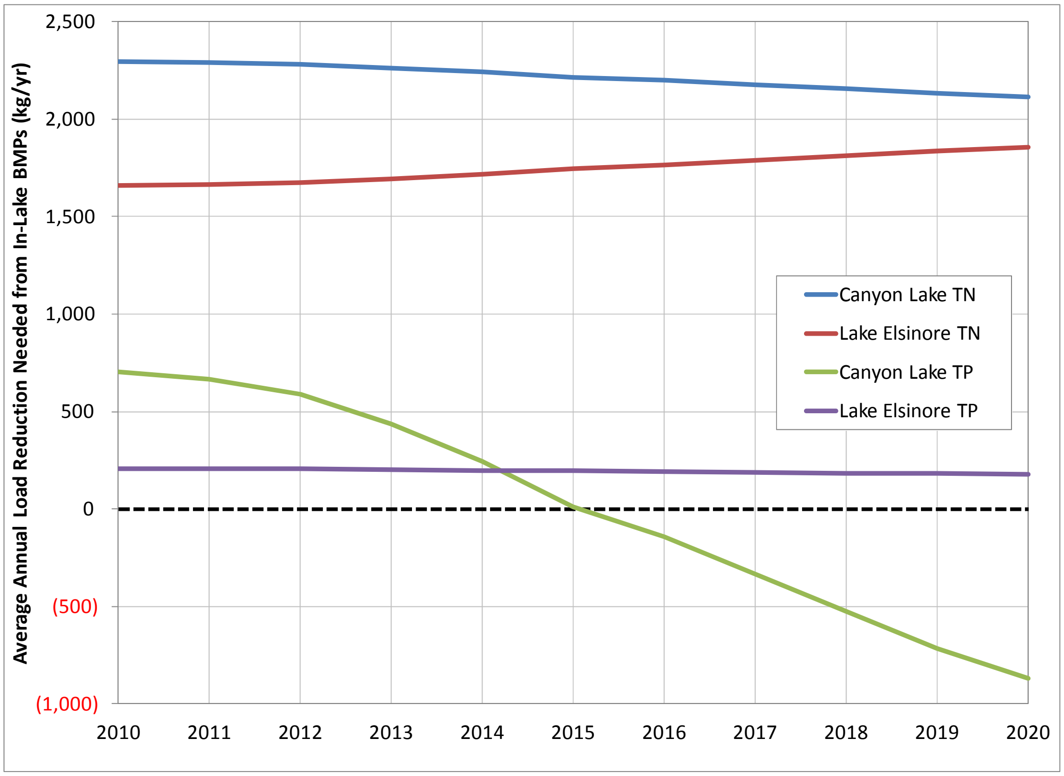


Figure 3-9
Projection of Remaining Load Reduction Needed, After Accounting for Watershed BMPs, to Reduce Existing Urban + Septic Loads to Respective WLAs and LAs

3.4 Load Reduction from In-Lake Remediation Projects

Reducing loads down to the WLA via watershed-based BMPs alone would be nearly impossible and extremely costly. Watershed-based BMPs would need to be designed to treat extreme storm events; whereas they are typically designed to treat smaller storm events (e.g. 1” or less of rainfall). Additionally, watershed controls would require significant rights-of-way to store and treat rainfall runoff from the 740 sq. mi. watershed. For example, using unit costs of $20,000-$80,000 per impervious acre treated (CWP, 2007) and an estimate of total watershed imperviousness of ~25,000 acres (30percent of urbanized land use), estimated total cost for the Lake Elsinore and Canyon Lake watersheds could range from $500 million to $2 billion if watershed BMPs were solely deployed.

Alternatively, for lake-nutrient TMDLs, water quality objectives can be achieved through the implementation of in-lake remediation projects in Lake Elsinore and Canyon Lake. Reduction of internal nutrient loads can offset reductions required from urban and septic sources that cannot be achieved with existing and planned watershed BMPs. Additionally, in-lake BMPs can be designed to achieve numeric targets for response variables in the TMDL, which include annual average chlorophyll-a and daily average DO. The following sections describe existing in-lake remediation activities ongoing in Lake Elsinore that provide sufficient nutrient reduction to offset the remaining load reduction needed to achieve WLAs and LAs for urban and septic sources. Also included is a new in-lake remediation project planned for Canyon Lake that will demonstrate compliance with the TMDL by achieving numeric targets for response variables chlorophyll-a and DO.

3.4.1 Lake Elsinore

Three in-lake remediation projects (or BMPs) are being implemented currently in Lake Elsinore: operation of aeration/mixing system, fishery management, and lake stabilization through the addition of reclaimed water. Various parties subject to the TMDL have implemented each of these projects through the Task Force. The Permittees have determined that support of aeration/mixing is sufficient to achieve in-lake nutrient load reduction needed to offset remainder of urban and septic load in excess of WLAs and LAs, as demonstrated in this section.

An average annual estimate of internal TP loading from sediments of 33,160 kg/yr for Lake Elsinore was found to exceed the TMDL allocation of 28,634 kg/yr, leaving no assimilative capacity for external loading (Regional Board, 2004). However, since the Lake Elsinore aeration/mixing system was planned for implementation at the time of TMDL adoption, a 35 percent TP reduction was assumed to create assimilative capacity and allow for development of LAs and WLAs for external sources, including open space. This assumed reduction in TP requires that all sources with WLA or LAs in the San Jacinto River watershed continue to operate the aeration system to achieve the presumed 35 percent TP reduction, referred to as the baseline sediment nutrient reduction requirement. For the MS4 Permittees, the baseline sediment nutrient reduction requirement is approximately 875 kg/yr, 7.5 percent of the total presumed load reduction of 11,606 kg/yr (35 percent of 33,160 kg/yr internal TP load). Table 3-15 provides the basis for determining the MS4 Permittee portion of the baseline sediment nutrient reduction requirement.

Table 3-15. Baseline Sediment Nutrient Reduction Requirement for MS4 Permittees

Nutrient Source	Watershed	WLA/LA Relative to Total Lake Elsinore WLA[1]	Baseline Sediment Nutrient Reduction Requirement (kg/yr)
Urban	Local Lake Elsinore	1.8%	208
	Canyon Lake [2]	3.2%	370
Septic	Local Lake Elsinore	1.0%	116
	Canyon Lake [2]	1.4%	168
Total		7.4%	861

1) For the local Lake Elsinore watershed, the urban WLA of 124 kg/yr is 1.8% and the septic LA of 69 kg/yr is 1.0% of total external load allocation of 6,922 kg/yr for reclaimed water, urban, septic, agriculture, and transfer from Canyon Lake

2) Transfer WLA from Canyon Lake watershed of 2,770 kg/yr is 40% of total external load allocation of 6,922 kg/yr. The urban and septic portion of the transfer from Canyon Lake to Lake Elsinore was assumed to be equal to the relative allocation of allowable loads in the Canyon Lake TMDL; urban WLA of 306 kg/yr is 8.0% and septic LA of 139 kg/yr is 3.6% of the total external load allocation of 3,845 kg/yr. Therefore the portion of baseline sediment nutrient reduction requirement assigned to urban and septic nutrient sources in Canyon Lake watershed is 3.2% (0.40 * 0.08) and 1.4% (0.40 * 0.036), respectively.

In addition to the baseline sediment nutrient reduction requirement, the MS4 Permittees in the local Lake Elsinore watershed must demonstrate ~200 kg/yr TP reduction and ~1,800 kg/yr TN reduction. Table 3-16 summarizes the water quality benefits of existing Lake Elsinore in-lake BMPs. As shown, the aeration system has more than enough capacity to meet baseline sediment nutrient reductions and additional needs to meet urban WLAs and septic LAs.

Table 3-16. Summary of Water Quality Benefits of Existing and Potential Supplemental Lake Elsinore In-Lake BMPs

In-Lake BMP	Nutrient / Response Variable	Benefit	Process
Aeration system	Phosphorus	11,606 kg/yr [1]	Suppression of sediment nutrient flux
	Nitrogen	11,600 kg/yr [3]	Nitrification / denitrification
		17,500 kg/yr [3]	Sequestration in benthic felt
	Dissolved Oxygen	~2 mg/L at bottom	Mixing of water column
Fishery management	Phosphorus	1,670 kg/yr [4]	Reduction of bioturbation by Carp
	Chlorophyll	Unknown	Reduction of zooplankton predation by Shad
Reclaimed water addition / lake level stabilization	Chlorophyll	10.2 ug/L	Increased depth increases light limitation needed for algal growth; increased habitat for zooplankton that predate algae; decreased salinity allows for zooplankton survival
	Nitrogen	1.5 kg/yr per AF of reclaimed water addition[5]	Increased bank vegetation density provides sink for nutrient
	Phosphorus	0.15 kg/yr per AF of reclaimed water addition[5]	Increased bank vegetation density provides sink for nutrient and stabilizes bottom sediment; Prevention of wind-driven re-suspension; dilution of Soluble Reactive Phosphorus (SRP) released from sediment

1) Assumed reduction in TMDL
2) Based on estimate of study of Lake Elsinore following aeration (Horne, 2009)
3) Based on study of bioturbation role in internal nutrient flux (Anderson, March 2006). Bioturbation by Carp are estimated to cause 6.9% of internal loading. Reduction of carp by 75% would reduce total TP internal load by 1,570 kg/yr (33,160*0.069*0.75)
5) Horne, 2011 developed a relationship between nutrient load reduction and reduced chlorophyll concentration of 10.2 ug/L per foot of water level rise observed in the summer season following the 2004-05 wet season. For an average annual water level increase of 1.7 ft achieved by addition of 6,000 AFY of reclaimed water, an estimated 0.9 tons TP and 9.0 tons TN would offset nutrients associated with reclaimed water addition The City of Lake Elsinore has a 50/50 cost share with EVMWD for current reclaimed water additions to stabilize lake levels.

Table 3-17 shows the portion of TP and TN load reduction required for each MS4 Permittee, including the baseline sediment nutrient reduction. If monitoring data show that the existing BMPs are not sufficient to achieve the WLA or in-lake response variable numeric targets, supplemental nutrient control strategies may be a part of an adaptive implementation strategy.

Since the 10 year running average in 2020 includes lake water quality data beginning in 2010, some portion of the compliance period will not reflect conditions with CNRP implementation underway. There are numerous elements of the CNRP intended to provide a margin of safety that could help alleviate the higher internal loading rates in the beginning years of the 2010-2020 compliance averaging period. The CNRP implementation schedule provides a roadmap to assist the MS4 Permittees in implementing key elements of the plan as efficiently as possible to increase the number of years when water quality benefits from internal loading offset are able to accrue.

Table 3-17. Lake Elsinore In-Lake BMP Load Reduction Requirements for MS4 Permittees

Jurisdiction	Baseline Sediment Nutrient Reduction (kg TP/yr)	Load Reduction Needed to Meet WLA (kg TP/yr)	Total TP Load Reduction Needed (kg/yr)	Total TN Load Reduction Needed (kg/yr)
Beaumont [1]	0.01		0.01	
Canyon Lake	20	10	30	57
Hemet [1]	29		29	
Lake Elsinore[2]	207	19	226	627
Menifee	108	4	112	23
Moreno Valley [1]	169		169	
Murrieta [1]	0.4		0	
Perris [1]	49		49	
Riverside [1]	4		4	
Riverside County	215	77	293	444
San Jacinto [1]	0.04		0.04	
Wildomar	73	85	158	594
Total	875	195	1,070	1,745

1) MS4 Permittees in Canyon Lake watershed responsibility is only to meet the baseline sediment nutrient reduction requirement only

2) The City of Lake Elsinore currently operates several in-lake treatment systems that result in load reductions exceeding their regulatory requirements including aeration, fishery management and lake water addition.

3.4.2 Canyon Lake

This compliance analysis for Canyon Lake uses response targets of nutrient related impairments, chlorophyll-a and DO, to demonstrate compliance using a lake water quality model, in lieu of achieving load reductions needed to meet WLAs and LAs for nutrients TP and TN. The Riverside County MS4 Permit allows the Permittees to use the response targets exclusively to demonstrate compliance with the TMDL (Order R8-2010-0033, Section VI.D.2.k.ii). The following sections describe how the use of alum additions will achieve compliance with the response targets for chlorophyll-a and DO.

A one dimensional lake water quality model, DYRESM-CAEDYM, was developed by the Task Force for use in evaluating nutrient management strategies for Canyon Lake and Lake Elsinore. The analysis of in-lake nutrient management alternatives to achieve response targets does account for estimated load reductions from watershed BMPs included in this CNRP by reducing daily inflow loads to DYRESM-CAEDYM. Since watershed load reductions are estimated on an annual basis, an assumption was made that percent load reductions are roughly equivalent for different seasons and storm event sizes, allowing for daily inflow loads reductions at the same percentage as annual reductions (Table 3-18). Table 3-18 includes additional watershed load reductions projected from implementation of Western Riverside County Agricultural Coalition's (WRCAC) agriculture nutrient management plan (AgNMP) for the CL/LE Nutrient TMDL and from expectation of continued improvement to vehicle emissions as a result of more stringent federal and state air quality standards (State Implementation Plan, South Coast Air Quality Management District).

The Task Force has completed detailed evaluations of aeration, oxygenation, and chemical addition (Anderson, 2008; CDM, 2011; Anderson, 2012b; Anderson, 2012c). Based on these evaluations, the Task Force has determined that chemical addition, using aluminum sulfate (alum), is the most effective in-lake nutrient control strategy to achieve interim numeric targets for the response variables, chlorophyll-a and DO. Appendix C provides the basis for this determination.

Table 3-18. Projected External Nutrient Load Reduction to Canyon Lake from all Jurisdictions with Allocated Loads

Nutrient Reduction Source	TN Load Reduction (kg/yr)	TP Load Reduction (kg /yr)
Land use change (2003 to 2010)	2828	818
Stormwater program implementation	955	182
Future urbanization w/ LID (2010 to 2020)	-217	649
Atmospheric Deposition [1]	384	0
AgNMP Projects	835	208
Estimated Load Reduction	4,785	1,857
External Load to Lake from 2010 Model Update	32,209	8,932
% of TMDL External Load	15%	21%

1) Reduced emissions of NOx from new air quality standards are expected to reduce atmospheric NOx concentrations in southern California by 60% (State Implementation Plan, South Coast Air Quality Management District). Based on recent TMDL implementation planning in the Chesapeake Bay, it was assumed this reduced NOx concentration could translate into 20% less TN load from direct atmospheric deposition over Canyon Lake. This reduction does not account for reduced deposition and subsequent washoff from watersheds.

3.4.2.1 Chlorophyll-a Response Target

When alum is added to a waterbody, an aluminum hydroxide precipitate known as floc is formed. The floc binds with phosphorus in the water column to form an aluminum phosphate compound which will settle to the bottom of the lake or reservoir. Once precipitated to the bottom of the reservoir, the floc will also act as a phosphorus barrier. It binds any phosphorus released from the sediments during normal nutrient cycling processes that occur primarily under anoxic conditions such as those found in much of the hypolimnion at Canyon Lake. The aluminum phosphate compounds are insoluble in water under most conditions, including those in Canyon Lake, and will render all bound phosphorus unavailable for nutrient uptake by aquatic organisms. It is through the reduction of bioavailable phosphorus that alum additions reduce the growth of algae in Canyon Lake, as measured by chlorophyll-a concentration in water samples.

Algae need both nitrogen and phosphorus for growth. The limiting nutrient is the one that is completely used for algal growth while some of the other still remains in its bioavailable form. Thus, only reductions of the limiting nutrient would be expected to generate reductions in algal growth. A Redfield ratio of TN to TP of greater than 7 suggests the waterbody in phosphorus limited, while a ratio less than 7 suggests the waterbody in nitrogen limited. Historical water quality data for Canyon Lake shows that the system is weakly nitrogen limited (Figure B-18). However, alum additions are only effective for addressing phosphorus. Thus, Canyon Lake alum additions are designed to reduce phosphorus sufficiently to create a condition of phosphorus limitation before generating any positive results toward compliance with the chlorophyll-a response target.

Seasonality

Generally, algal blooms in Canyon Lake occur at similar times of year (Figure 3-10) and are primarily a function of nutrient loading trends. For this reason, the Alum applications described in this CNRP were developed to reduce seasonal chlorophyll-a concentrations crested by these algal blooms, despite the numeric target being an annual average basis. This approach provides an additional MOS for compliance. In addition, this approach is more likely to gain support from the public as it addresses the impairment as it occurs. I.e. clears up the lake water.

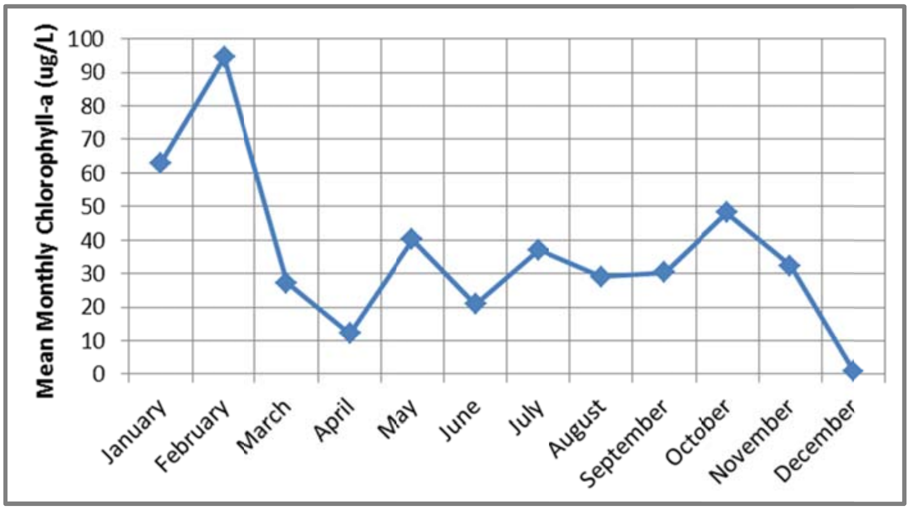


Figure 3-10
Mean Monthly Chlorophyll-a in Main Body of Canyon Lake

The first algal bloom occurs around February and is caused by the presence of nutrient rich external loads in dissolved or suspended particulate form that remain in Canyon Lake at the end of the wet season, coincident with increasing daylight hours and water temperatures. The second algal bloom occurs around October and is caused by turnover of the lake, which brings nutrient enriched water from the hypolimnion to the photic zone where it serves as a food source for algae. This source of nutrients comes from internal loads released from bottom sediments into the hypolimnion during the period of thermal stratification (roughly March through October). The presence of anoxic conditions in the hypolimnion increases the rate of nutrient flux from bottom sediments and subsequent loading of nutrients to photic zone at turnover. To address both periods of enhanced algal growth, alum applications to Canyon Lake are proposed twice per year, once around February 15th, and again around September 15th.

Analysis for Main Body

The DYRESM-CAEDYM model was used to estimate the reduction of bioavailable phosphorus that would be needed to limit algae growth, and maintain average annual chlorophyll-a concentration at less than 25 ug/L in all hydrologic years. Adsorption isotherms were then used to estimate the required dose of alum needed to reduce phosphorus from current levels to the target concentration. Results showed that a dose of 10 mg/L of alum (~1 mg/L as Al) would effectively reduce 10-year averages of chlorophyll-a from ~35 ug/L to less than ~5 ug/L by reducing TP from ~0.31 mg/L to ~0.15 mg/L (Anderson, 2012e). The model predicted a significant reduction in chlorophyll-a despite average TP concentrations being above the TMDL numeric target of 0.1 mg/L. The reason for this is that the reduction accounts for most of the bioavailable pool of phosphorus (i.e. dissolved orthophosphate form). At a relatively low dose of 10 mg/L, alum forms a less than typical floc size or “microfloc”, which has a longer residence time as it settles through the water column. The longer residence time allows for chemical processes needed to bind dissolved forms of phosphorus relative to heavier doses (50-100 mg/L) that largely only provide physical entrainment of particulates as a larger floc settles through the water column (Moore et al., 2009). EVMWD conducted jar tests to determine the reduction of TP that could be achieved at varying doses of alum (see Attachment C). Jar test results from the two Main Body monitoring locations (CL07 and CL08) showed that a dose of 10 mg/L alum would result in a TP reduction of ~0.15 mg/L, which presumably is mostly in the form of dissolved orthophosphate.

Analysis for East Bay

The one dimensional DYRESM-CAEDYM model simulates a lake wide average vertical profile of water quality, therefore areas of relatively greater concern for chlorophyll-a are averaged with areas of typically better water quality. of a particular interest to the MS4 Permittees is the East Bay of Canyon Lake. The East Bay is shallower than the Main Body, receives runoff from a different subwatershed, has higher nutrient concentrations, more dense and persistent algal blooms, and experiences minimal lateral mixing with the Main Body of the lake. A separate analysis using CDM Smith’s Small Lake Assessment Model (SLAM) was completed for this zone of Canyon Lake to assess whether alum can be effective for reducing chlorophyll-a (CDM Smith, 2012). Once calibrated using historical nutrient and chlorophyll-a data (2007 – 2010), SLAM was used to test the effect of reduced water column TP on chlorophyll-a. SLAM results suggest that TP would need to be reduced to ~0.05 mg/L to reduce seasonal chlorophyll-a concentrations to below the numeric target of 25 ug/L (Figure 3-11). This differs from the DYESM-CAEDYM results, because SLAM does not partition dissolved and particulate forms of phosphorus. The alum application in the East Bay is heavier than in the Main Body and will therefore not act as a microfloc targeting primarily dissolved orthophosphate as is planned for the Main Body. Thus, simulation of total phosphorus is appropriate for the East Bay as additional removal of particulate phosphorus will occur.

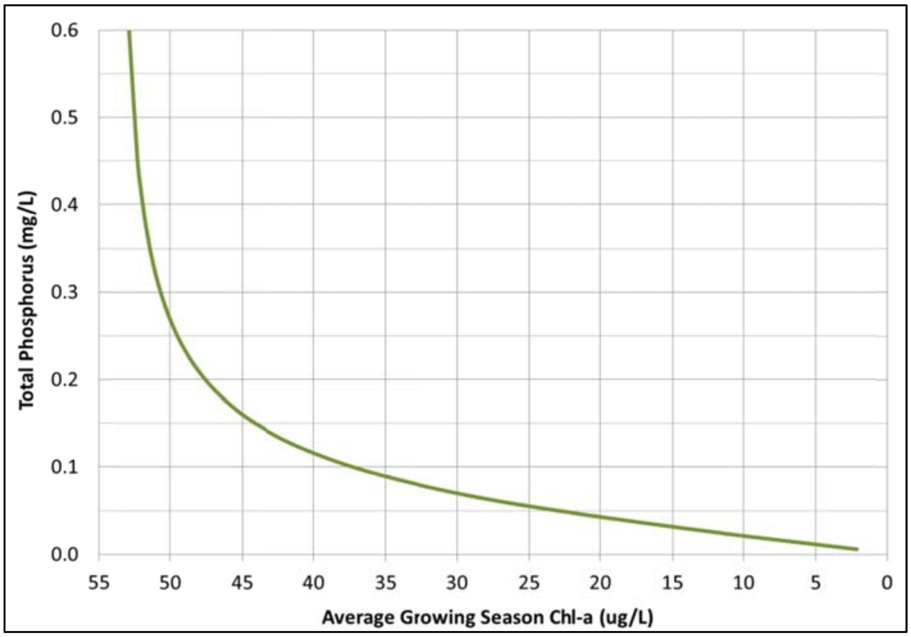


Figure 3-11
SLAM Results Showing Chlorophyll-a for Varying Reductions in Total Phosphorus during Growing Seasons

EVMWD jar test results from the two East Bay monitoring locations (CL09 and CL10) showed that a dose of 20-40 mg/L alum would result in a TP of ~0.05 mg/L, therefore a heavier dose of 30 mg/L alum (~3 mg/L as Al) was selected for East Bay alum applications (Attachment C).

3.4.2.2 Dissolved Oxygen Response Target

The numeric target for DO in the CL/LE Nutrient TMDL is not limited to conditions that exist "as a result of controllable water quality factors", which is contained in the Basin Plan WQO for DO. The TMDL Staff Report recognizes uncertainty and comes to the resolution that "as the relationship between nutrient input and dissolved oxygen levels in the lakes is better understood, the TMDL targets for dissolved oxygen can be revised appropriately to ensure protection of aquatic life beneficial uses". Accordingly, the Task Force developed a DYRESM-CAEDYM model scenario to assess DO conditions above and below the thermocline if the watershed were completely undeveloped (Anderson 2012d). The cumulative frequency plots in Figure 3-12 show the full range of daily results. For the hypolimnion, exceedences of the DO WQO of at least 5 mg/L occur roughly 50 percent of the time in the predevelopment scenario, which is intended to represent the uncontrollable portion of low DO conditions.

For the epilimnion (model output average for top 3 meters of water column), there are no exceedences of the DO WQO in the predevelopment or watershed BMP + alum condition. However, DO monitoring data shows that exceedences of the DO target do occur in the epilimnion, but are limited to the period when the lake is turning over. Turnover occurs around October and involves destratification, which allows for low DO water from bottom of the lake to mix with surface waters. This problem is also expected to occur under pre-development conditions; however, the degree to which the current rate of non-compliance may differ from pre-development conditions has not yet been modeled. Thus, it can be concluded that Canyon Lake is currently meeting interim numeric targets (see Table 1-1) except for a temporary period when the lake is turning over.

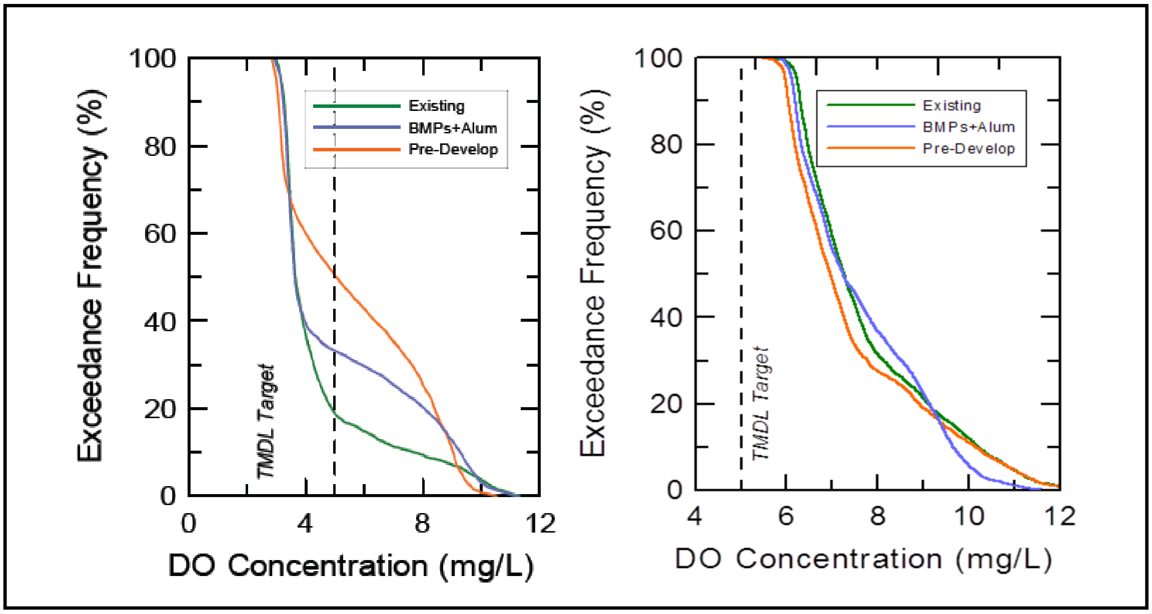


Figure 3-12

Cumulative Frequency of Daily Average DO in hypolimnion (left) and epilimnion (right) for DYRESM-CAEDYM Simulations of Existing, Pre-development, and with CNRP Implementation Scenarios

The combination of watershed BMPs and alum additions will not directly increase dissolved oxygen within Canyon Lake; however, over time, the indirect benefit of reduced algal growth and die-off/settling will reduce sediment oxygen demand, and therefore reduce anoxic conditions at sediment-water interface. In turn, more oxic conditions at the sediment-water interface will reduce the flux of nutrient from bottom sediments to the water column, which would provide additional reductions in algal growth and die-off/settling. Figure 3-12 shows that implementation of watershed BMPs and alum additions over a 10-year period would be expected to provide significant progress toward returning exceedence frequency of WQOs to pre-development levels. However, these indirect benefits will not be realized immediately, given that the half-life of settled nutrients in Canyon Lake is estimated to be approximately 10 years (Anderson, 2012a). Attachment C includes a slideshow presentation, given by Michael Anderson on February 14, 2012, describing kinetic modeling completed to assess the length of time settled nutrients are rendered no longer bioavailable, or inert, in Canyon Lake bottom sediments.

3.4.2.3 Canyon Lake In-Lake BMP Implementation

Table 3-19 shows the plan for alum additions to Canyon Lake for both the wet and dry season applications. These applications are based on the evaluation of an effective dose for the Main Body and East Bay as well as an assessment of seasonality in algal growth to determine the appropriate times of year to conduct the alum additions. The estimate of treated TP with the proposed alum applications is roughly twice the combined TP load from urban (1709 kg/yr) and septic (56 kg/yr) sources to Canyon Lake based on the 2010 update to the watershed model used for the TMDL linkage analysis (Tetra Tech, 2010). Thus, the proposed alum addition plan would provide more than enough TP removal to offset the load reduction needed to meet the WLA for urban and LA for septic sources, as well as providing excess credits for other potential project proponents.

Table 3-19. Alum Addition Plan for Canyon Lake (2013-2015)

Zone	Application Date	Description	Alum Dosage (mg/L)	Alum Application (kg dry alum)	Treated TP (kg)
Main Body	February	Water column stripping following wet season storms prior to spring algal bloom	10	70,000	685
	September	Water column stripping prior to turnover/fall algal bloom and suppression of internal sediment nutrient flux	20	140,000	1,309
East Bay	February	Water column stripping following wet season storms prior to date of historic algal bloom occurrence	30	50,000	808
	September	Water column stripping prior to turnover in deeper sections and fall algal bloom	30	50,000	808
			Annual Total	310,000	3,609

One concern with the use of alum in lakes is the possible effects on aquatic life. There is potential for acute or chronic aluminum toxicity to aquatic life in surface waters (e.g. zooplankton) that receive the initial dose of alum. Studies of aluminum toxicity from similar source waters show that this is not a likely condition, especially considering the low dose proposed for Canyon Lake. Jar tests performed at each of the Canyon Lake compliance monitoring stations provided an approximation of the dissolved aluminum that may be present in the water column immediately following the alum application. With dissolved aluminum concentration ranging from 200-600 ug/L, acute or chronic toxicity is not expected. However, to ensure that the alum additions in Canyon Lake are safe for aquatic life, the Permittees first step to implement the CNRP will involve conducting toxicity tests using ambient water from different parts of Canyon Lake prior to alum addition. If these tests find there is no impact to aquatic life from the proposed alum additions, such data will be used to develop a case for a negative declaration in the CEQA analysis.

Beginning in September 2013, assuming CEQA compliance is complete, alum application will be performed according to the schedule shown in Table 3-19. After the fifth alum application in September of 2015, the MS4 Permittees will evaluate water quality data in the lake, and determine whether response targets are achieved or if modification to the alum application plan or potential supplemental BMPs may be needed to achieve response targets in Canyon Lake for chlorophyll-a and DO (see Table E-1 in Attachment E for detailed implementation schedule).

In 2016, the TMDL will be reopened to revise the final numeric target for DO to incorporate controllability by means of an allowable exceedance frequency representative of a pre-development condition in the watershed. The 2012 DYRESM-CAEDYM simulations of a lake water quality for a pre-development level of watershed nutrient loads will be used to represent an uncontrollable frequency of exceeding the final DO target of at least 5 mg/L in the hypolimnion. A cumulative frequency plot of average daily DO data from the two year period of alum applications (Sep 2013 through Sep 2015) will be compared to the pre-development cumulative frequency to determine whether sufficient improvement to DO was achieved with the alum applications.

3.5 Uncertainty

WLAs and LAs for TP and TN in Lake Elsinore are expected to be achieved following implementation of watershed and in-lake BMPs included in the CNRP. For Canyon Lake, the proposed watershed BMPs and in-lake treatment will significantly exceed the TP load reduction needed to meet the WLA and LA for urban and septic sources; however, the CNRP will not provide sufficient load reduction to meet the WLAs and LAs for TN in the Canyon Lake watershed. Instead, the CNRP is tailored to achieve the response targets for chlorophyll-a, and DO in Canyon Lake.

For both lakes, the development of the CNRP involved a conservative approach to account for uncertainty in the expected benefits of watershed and in-lake nutrient management BMPs proposed. The following sections characterize some of these sources of uncertainty that could cause the CNRP to be more or less effective than expected.

3.5.1 Use of 2010 Watershed Model Update

Load reduction requirements for this CNRP compliance analysis were based on existing load estimates from the 2010 watershed model update. Since the adoption of the TMDL, urban land use has increased while agricultural land use has declined and this trend is expected to continue as the watershed approaches a buildout condition. Accordingly, the 2010 watershed model update generally showed an increased nutrient load from urban sources and a decreased nutrient load from agricultural sources. Septic loads also decreased based on the more accurate accounting of septics resulting from the 2007 SSMP. CAFO loads increased. The TMDL did not account for future changes in land use distribution in the watershed. To assess the impact of these changes on the feasibility of meeting the TMDL, WLAs were converted to allowable per acre loading rates using land use acreage used to develop the TMDL and the 2010 watershed model update (Figure 3-13). Figure 3-13 shows that maintaining the same mass based WLAs, as set in the TMDL, would reduce the allowable per acre loading rate for urban and septic sources, and increase the allowable per acre loading rate for agricultural and CAFO sources. Ultimately, this issue should be addressed in a supplemental Basin Plan Amendment as per acre loading rates should be based on achievable wash-off rates for each land use and not subject to change due to land use conversion.

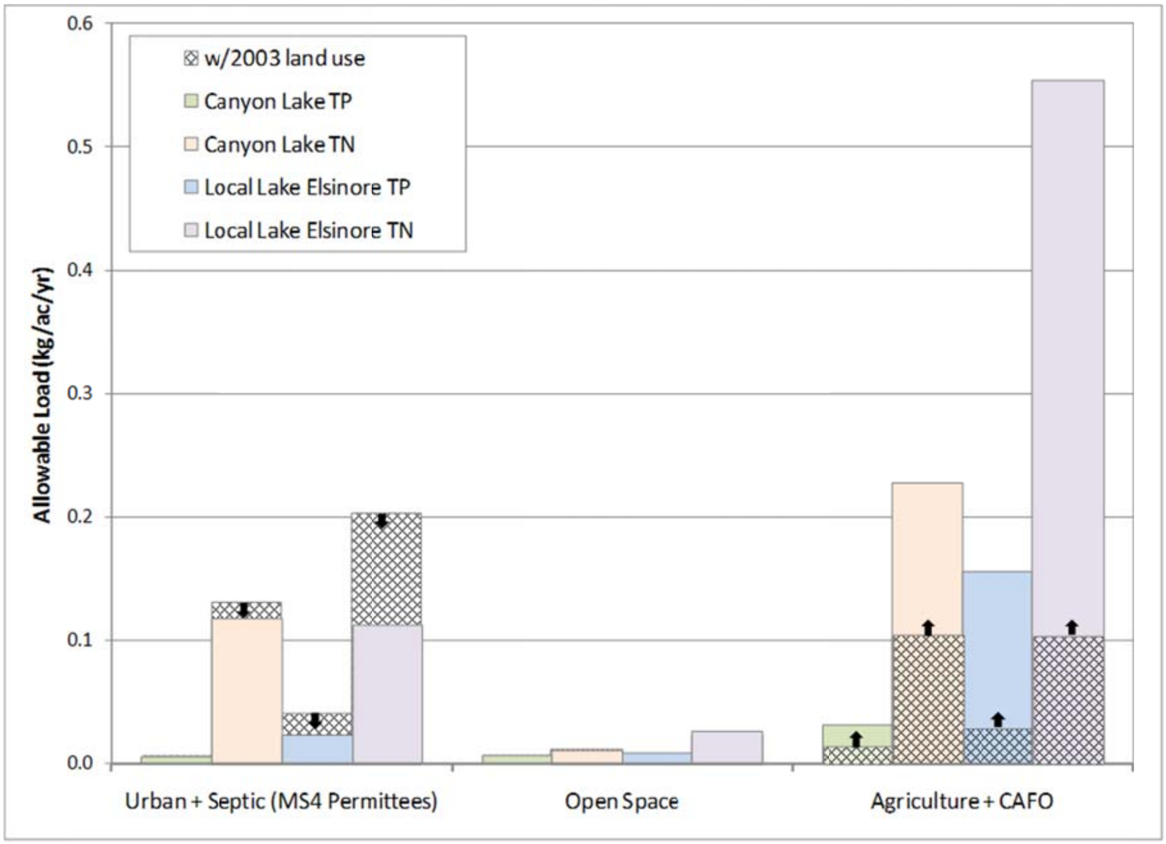


Figure 3-13
WLAs Converted to Allowable per acre Loading Rates

3.5.2 Potential Benefit of Margin of Safety BMPs

Studies have shown that education and outreach programs and/or ordinance enforcement actions may result in a measureable change in human behavior, thereby providing a reduction in a specific source of nutrients available for washoff into MS4s in the watershed. However, quantification of potential washoff reductions entails estimations with a high level of uncertainty. This compliance analysis estimates the potential washoff reduction for education, outreach and enforcement programs, but then uses these estimations as a "margin of safety" for MS4 compliance with the TMDL. Therefore, the load reduction values of these BMPs are not included to attain TMDL WLA..

To approximate the additional MOS provided by such BMPs for this CNRP, it was assumed that 15 percent of pollutant sources in the watershed could be reduced from current conditions with enhanced and targeted education and outreach programs or by enforcement of existing ordinances. Rough estimates were developed to approximate the additional MOS provided by improvements to how residents manage potential sources of nutrients in the watershed.

The basis for these estimates involves an assessment of the relative role of targeted nutrient sources in the downstream load of nutrients. Estimates of reductions in loads to Canyon Lake also incorporated a loading factor to account for nutrients that would be retained in-stream between the source area and lake inflow without BMP implementation (see Table 3-3).

In the case of the CNRP, education and outreach programs and ordinance enforcement actions are focused on three main sources of nutrient in urban watersheds; fertilizer, pet waste, and green waste. A nitrogen budget for an urban watershed developed for the Central Arizona-Phoenix long term ecological research (LTER) site found that fertilizer and pet waste may account for as much as 60 percent and 14 percent of total nitrogen inputs (Baker et. al., 2001). Also, the study estimated green waste to account for 28 percent of outputs in the total nitrogen budget. Consequently, there is significant opportunity for reducing downstream nitrogen loads with improved management of these sources in the urban watershed. Load reductions for MOS BMPS targeting each of these sources are described below:

- To quantify reductions in mobilization of fertilizer from application sites to MS4 drainage facilities, several factors were applied to an estimate of the total nutrient load applied to fertilized lawns (assumed to cover 20 percent of the total urban acreage) in the local Lake Elsinore and Canyon Lake watersheds. According to a UCR Agricultural and Natural Resources Publication (Pub No. 8065), typical fertilizer application rates for grass lawns in southern California are 20 kg/ac/yr nitrogen and 7 kg/ac/yr phosphorus. Several studies have found nutrient loss in surface runoff as a result of fertilizer application to be about 2-5 percent for nitrogen (Groffman et al., 2004; Baker et al., 2001) and less than 10 percent for phosphorus (Soldat and Petrovich, 2008). Thus, a conservative factor of 2 percent was used to estimate the mass of nutrients that could be reduced through fertilizer management that is 15 percent more effective than current conditions (Table 3-20).

- For MOS BMP implementation addressing pet waste, the method used to estimate nutrient washoff involved several factors to convert dog population to nutrient accumulation, and loss from lawns during a rain event. The population of dogs in the Canyon Lake and Lake Elsinore watersheds was approximated by applying a US average dog ownership ratio of 1 dog per four persons to the approximate population within the watershed (see Table B-1). An average dog generates about 125 kg/yr of feces which has a composition of roughly 1 percent nitrogen and 1 percent phosphorus. If 50 percent of dog feces is available for washoff (i.e. not picked up), then the annual accumulation would be about 0.6 kg/dog/yr for both TP and TN. For pet waste it was assumed that loss of nutrients in surface runoff is 1 percent, which is half of the abovementioned value used for fertilizer, a more readily soluble material. Assuming 15 percent effectiveness in the MOS BMPs, the reduction in nutrient washoff related to pet waste management is estimated, as shown in Table 3-20.

- The method used to estimate nutrient washoff reduction from improved green waste management on impervious surfaces, such as roads and driveways, involved application of the same model developed to simulate benefits of street sweeping (see Section 3.3.1). The buildup/washoff model determined a washoff reduction benefit of improved green waste management of approximately 0.07 kg/mi/yr for TP and 0.45 kg/mi/yr for TN. The basis for the buildup model was a study of green waste in Plymouth and Maple Grove, MN, which found a grass clipping accumulation rate on average to be 3 kg/curb mi/day and a composition of TP and TN in grass clippings of 0.3 and 2.0 percent, respectively (Minnesota Pollution Control Agency, 2008). Assuming 15 percent effectiveness in the MOS BMPs, the buildup of green waste on impervious areas was reduced for the buildup/washoff simulation. The estimated reductions from MOS BMPs targeting green waste left on impervious surfaces, such as roads and driveways, are shown in Table 3-20.

The Permittees believe these MOS BMPs offset the other sources of uncertainty in the determination that estimated watershed loads reductions assumed in the lake water quality model, will be achieved. Specifically, estimates of reduction in nutrient washoff from MS4 drainage areas involved many assumptions on effectiveness, urban growth rates, and stormwater program implementation..

Table 3-20. Estimate of Potential Load Reduction provided by Margin of Safety BMPs which Target Human Behaviors

Targeted Source	Variable	Local Lake Elsinore	Canyon Lake below Mystic Lake[1]
Fertilizer Management	Urban Acreage	8,469	57,609
	TP Reduction (kg/yr)	34	120
	TN Reduction (kg/yr)	102	415
Pet Waste Management	Dog Population	22,259	129,043
	TP Reduction (kg/yr)	17	50
	TN Reduction (kg/yr)	17	58
Green Waste Management	Residential Road Miles	137	959
	TP Reduction (kg/yr)	9	34
	TN Reduction (kg/yr)	62	261
Total MOS BMPs	TP Reduction (kg/yr)	60	204
	TN Reduction (kg/yr)	180	733
% of Required Load Reduction[2]	TP	14%	15%
	TN	8%	20%

1) Incorporates loading factors of 52 percent for TP and 60 percent for TN to account for nutrients that may have been retained in-stream between the source areas and Canyon Lake without BMP implementation

2) Load reduction required in TMDL, used for developing the CNRP already includes a 10 percent MOS, thus these BMPs provide additional MOS

3.5.3 Controllability of TMDL Allocations and Response Targets

3.5.3.1 TMDL Allocations for Lake Elsinore

This CNRP uses WLAs and LAs to demonstrate compliance with the TMDL in Lake Elsinore. These allocations are evaluated by assessing 10-year running averages of modeled TP and TN loading to Lake Elsinore. The 2010 watershed model was modified to also evaluate watershed loads to Canyon Lake and Lake Elsinore[1] for a pre-development or natural condition in the San Jacinto River watershed. Figure 3-14 compares existing and pre-development scenarios annual loading and 10-year running averages for TP and TN in the local Lake Elsinore and Canyon Lake watersheds.

These charts show that even in a predevelopment scenario, it is common for wetter hydrologic years to result in 10-year average watershed loads in excess of the WLA, which suggests that numeric response targets in Lake Elsinore and Canyon Lake may not be attained even under natural conditions. Thus, it may be appropriate to propose a revision of numeric targets from use of daily, seasonal, or annual averages, to incorporate a provision to allow for a natural background standard. The Permittees reserve the right to request such amendments should effectiveness data indicates that the current TMDL is unattainable. The MS4 Permittees plan to implement a CNRP that will achieve the WLAs, as set in the TMDL. However, if implementation demonstrates that load reduction targets cannot feasibly be met,

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[1] The 2010 watershed model did not explicitly simulate loading to Lake Elsinore for the pre-development scenario. Instead, nutrient loading rates for open space from the calibrated model, were extrapolated over the entire local Lake Elsinore watershed to approximate loading. This approach neglects decay that may have occurred as nutrients are transported from sources areas to Lake Elsinore.

then the MS4 Permittees may recommend that the TMDL be revised to consider naturally attainable water quality standards and/or achievable wash-off rates.

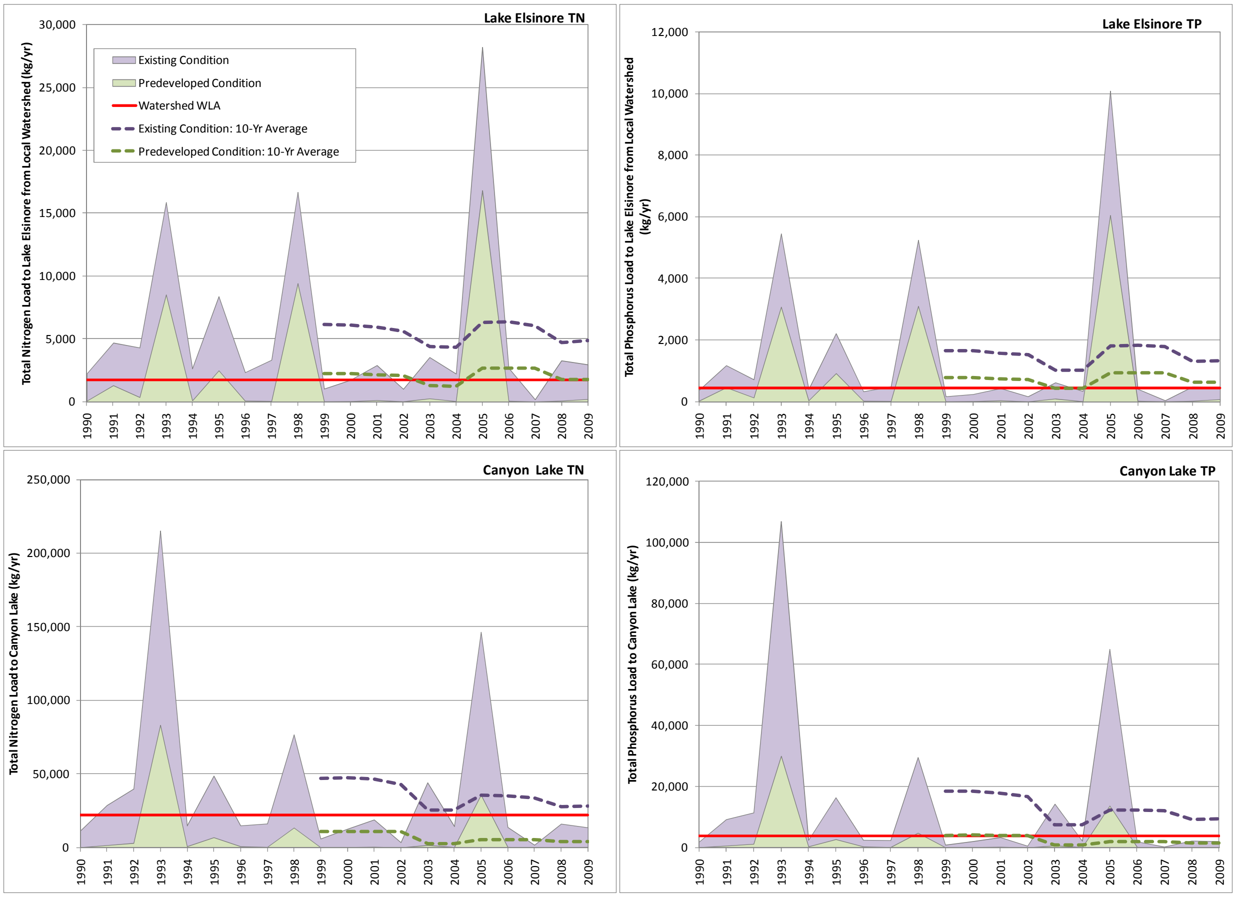

Figure 3-14
Comparison of Modeled Existing Load with Natural Conditions Assessment Scenario

3.5.3.2 Lake Water Quality Response Targets for Canyon Lake

The DYRESM-CAEDYM simulation projected that with implementation of the CNRP and AgNMP, annual average chlorophyll-a for the entire lake would be 5 ug/L with wetter years reaching 10 ug/L. Therefore, the model projects that the CNRP will achieve compliance with the final chlorophyll-a response target of an annual average of 25 ug/L, irrespective of hydrologic fluctuation. This model estimates a lake-wide average chlorophyll-a, which is the same metric used to determine compliance with the response target per the TMDL. Even if the lake-wide average chlorophyll-a meets the response target, specific areas of Canyon Lake during critical seasons may still experience more algal growth than others, such as East Bay. For this reason, a heavier dose of alum is planned for shallower areas to drop TP below 0.1 mg/L, furthering limiting the available phosphorus needed for algae to grow, based on East Bay specific simulations using SLAM.

These models rely on a relationship between the dose of alum addition and resultant phosphorus reduction, which was based on one set of jar tests from each of the four compliance monitoring stations, collected in dry season of 2012 (see Attachment C). These jar tests may not be representative of potential ambient water quality when alum additions are implemented in 2013-2015, and thus the expected benefits may vary from the DYRESM-CADYM simulation. For example, if pH is higher than it was in the jar test samples, then a portion of the applied alum would be spent acidifying the water before forming an effective aluminum hydroxide floc that is able to bind with phosphorus. The Permittees will continually evaluate water quality data to assess whether the alum applications are performing as expected or if the plan should be modified.

Uncertainty is greatest when it comes to the ability for alum to achieve the final DO response target for the hypolimnion, even after accounting for the potentially uncontrollable exceedences associated with a predevelopment condition in the watershed. The DYRESM-CAEDYM results showed a reduction in exceedence frequency from 80 to 65 percent of the time, attributable to the indirect benefits of reduced nutrient cycling and associated sediment oxygen demands. Anderson 2012a suggests that such benefits may continue to accrue over several decades, but there is much uncertainty as to the ultimate potential for DO conditions in the hypolimnion. Consequently, the Permittees have developed adaptive management into this CNRP. In 2016, the Permittees will evaluate the effectiveness of alum applications for DO in the hypolimnion and determine whether a supplemental in-lake project for DO, such as aeration or oxygenation, would be needed.

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Attchment A
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Attachment A
TMDL Implementation

A.1 Introduction

TMDL coordination efforts have been underway since August 2000, well before adoption of the Lake Elsinore and Canyon Lake Nutrient TMDLs ("Nutrient TMDLs"). These activities were coordinated and administered through the Lake Elsinore San Jacinto Watersheds Authority (LESJWA), a joint powers authority. The Santa Ana Regional Water Quality Control Board (Regional Board) adopted the Nutrient TMDLs on December 20, 2004; the Nutrient TMDLs became effective on September 30, 2005, after EPA approval. The existing TMDL stakeholders formally organized into a funded TMDL Task Force in 2006. This Task Force in coordination with LESJWA has been actively involved in the implementation of the TMDL requirements. The following sections describe the organizational structure and responsibilities of LESJWA and the Task Force and status of TMDL implementation activities, as applicable to the MS4 Permittees.

A.2 Lake Elsinore San Jacinto Watersheds Authority

LESJWA is made up of representatives from the Santa Ana Watershed Project Authority, Elsinore Valley Municipal Water District, City of Lake Elsinore, City of Canyon Lake and County of Riverside. LESJWA was formed in April of 2000 after California voters passed Proposition 13, a bond measure to fund water projects throughout the State. Proposition 13 earmarked $15 million for LESJWA to implement projects to address the impairments in Lake Elsinore and Canyon Lake. LESJWA is charged with improving water quality and protecting wildlife habitats, primarily in Lake Elsinore, but also in Canyon Lake and the surrounding watershed. Several LESJWA projects are central to the stakeholder TMDL compliance strategies, including:

- Lake Elsinore Aeration System
- Lake Elsinore Wetland Enhancement
- Lake Elsinore Carp Removal
- Lake Elsinore Axial Flow Pumps
- Lake Elsinore Island Wells
- Lake Elsinore Dredging Project

LESJWA has conducted several studies to evaluate lake conditions, alternative management measures and potential funding mechanisms.

These efforts provide the basis for ongoing compliance work of the TMDL Task Force. In addition, the TMDL Task Force continues to rely on the LESJWA Technical Advisory Committee for technical guidance.

A.3 Lake Elsinore and Canyon Lake TMDL Task Force

In December 2004, all responsible parties named in the TMDL began the process of creating a formal cost-sharing body, or Task Force, to collaboratively implement various requirements defined in the implementation plan for the nutrient TMDLs. A Task Force Agreement was signed March 5, 2007. The purpose of the Task Force is to conduct studies necessary to collect data to analyze the appropriateness of the TMDL, identify in-lake and regional watershed solutions, pursue grants, coordinate activities among all of the various stakeholders, and recommend appropriate revision to the Basin Plan language regarding Lake Elsinore and Canyon Lake based on data collection and analysis. The Task Force includes the following participants:

- County of Riverside
- Riverside County Flood Control & Water Conservation District
- City of Beaumont
- City of Canyon Lake
- City of Hemet
- City of Lake Elsinore
- City of Menifee
- City of Moreno Valley
- City of Murrieta
- City of Riverside
- City of San Jacinto
- City of Wildomar
- Elsinore Valley Municipal Water District
- Eastern Municipal Water District
- California Transportation Department
- California Department of Fish & Game
- March Air Reserve Joint Powers Authority
- US Air Force (March Air Reserve Base)
- Western Riverside County Agriculture Coalition on behalf of Agricultural & Dairy Operators in the San Jacinto River Basin

SAWPA serves as the administrator for the Task Force. In this role, SAWPA provides all Task Force meeting organization/facilitation, secretarial, clerical and administrative services, management of Task Force funds, annual reports of Task Force assets and expenditures and hiring of Task Force authorized consultants. SAWPA maintains a website with all information developed to date through the Task Force: www.sawpa.org/roundtable-LECLTF.html.

A.4 TMDL Tasks Applicable to MS4 Permittees

The Nutrient TMDLs include 14 tasks in the TMDL implementation Plan (Resolution No. R8-2004-0037). Not all tasks are applicable to the MS4 Permittees. Table A-1 briefly describes each TMDL task, its relevance to the MS4 Permittees, and general status. Further discussion on the status and work performed for each task for which the MS4 Permittees have responsibilities is detailed in the subsections that follow.

A.4.1 Task 2.1 – Review and/or Revise Existing Waste Discharge Requirements, Riverside County MS4

When the TMDL was adopted, the Riverside County MS4 permit (Waste Discharge Requirements for the Riverside County Flood Control and Water Conservation District, the County of Riverside and the

Incorporated Cities of Riverside County within the Santa Ana Region, Area-wide Urban Runoff, NPDES No. CAS 618033; Regional Board Order No. R8-2002-0011) did not include requirements directly related to the TMDL Implementation Plan or require the Permittees to address the TMDL WLAs.

Since the adoption of the TMDL, a new MS4 permit has been adopted (NPDES No. CAS 618033; Regional Board Order No. R8-2010-0033). This permit not only requires completion of the tasks identified by the TMDL, but it also requires the preparation of this CNRP to address the Nutrient TMDL WLAs for urban runoff and LAs for septic sources.

A.4.2 Task 2.2 – Review and/or Revise Existing Waste Discharge Requirements, New Development, San Jacinto Watershed

In 2001 the Regional Board adopted Order No. 01-34 (NPDES No. CAG 618005) that established requirements for discharges of stormwater runoff associated with new developments in the San Jacinto Watershed. The TMDL stated that this Order would be rescinded once the Regional Board approves a WQMP under Order R8-2002-0011 (existing MS4 permit at time of TMDL permit adoption).

The Regional Board approved the MS4 program's revised WQMP (Order R8-2004-0080), which became effective September 17, 2004. Subsequent to the approval of this Order, the Regional Board approved Order R8-2005-0038 that amended Order 01-34 to state that projects that implement an approved WQMP are exempt from Order 01-34.

The Riverside County MS4 program is currently revising its WQMP again to incorporate LID-based BMP requirements contained in the most recently adopted MS4 permit (January 29, 2010). A draft WQMP was submitted to the Regional Board on July 29, 2011; a final WQMP was submitted June 28, 2012 and was approved by the Regional Board on October 22, 2012.

Table A-1. TMDL Implementation Plan Tasks Applicable to MS4 Permittees

Task No.	Task Name	Task Description	Compliance Date (per TMDL)	Relevance to Riverside County MS4 Permit and Status
Task 1	Establish new Waste Discharge Requirements (WDR)	Issue new WDR to Elsinore Valley Municipal Water District for supplemental discharges to Canyon Lake	March 31, 2006	Not applicable to MS4 dischargers; per Regional Board status is ongoing
Task 2	2.1 – WDR for Riverside County MS4 Permittees	Revise existing MS4 permit (Order R8-2002-0011) as needed to incorporate TMDL requirements	March 31, 2006	2002 MS4 permit was not revised; new MS4 permit issued on January 29, 2010 includes both TMDL requirements and requirement to complete CNRP.
	2.2 – Watershed-wide WDRs for Discharges of Storm Water Runoff associated with new developments in the San Jacinto Watershed	Rescind Order 01-34 when revised Water Quality Management Plan (WQMP) approved under Order R8-2002-0011	March 31, 2006	Revised WQMP approved by Order R8-2004-0080; Order R8-2005-0038 amends Order 01-34 to state that projects that implement an approved WQMP are exempt from Order 01-34
	2.3 – General WDR for Concentrated Animal Feeding Operations (CAFOs)	Revise existing General WDR (Order 99-11) as needed to incorporate TMDL requirements	March 31, 2006	Not applicable to MS4 dischargers; CAFP WDR adopted per Regional Board Order R8-2007-001
	2.4 – Waste Discharge and Producer/User Reclamation Requirements for the EVMWD, Regional Water Reclamation Facility	Revise Order No. 00-1 to take into consideration Lake Elsinore Recycled Water Pilot Project findings	March 31, 2006	Not applicable to MS4 dischargers; per Regional Board status is complete/ongoing-as needed
	2.5 – WDR for Eastern Municipal Water District (EMWD), Regional Water Reclamation System	If needed, revise order No. 99-5 to address EMWD discharge of recycled water to Lake Elsinore and to take into consideration Lake Elsinore Recycled Water Pilot Project findings	March 31, 2006	Not applicable to MS4 dischargers; per Regional Board status is complete/ongoing-as needed
	2.6 – WDR for US Air Force, March Air Reserve Base	Revise Order R8-2004-0033 to incorporate TMDL requirements	March 31, 2006	Not applicable to MS4 dischargers; per Regional Board status is complete/ongoing-as needed
Task 3	Identify Agricultural Operators	Regional Board will develop a list of all known agricultural operators in the San Jacinto watershed responsible for TMDL implementation	October 31, 2005	Complete

Table A-1. TMDL Implementation Plan Tasks Applicable to MS4 Permittees (Continued)

Task No.	Task Name	Task Description	Compliance Date (per TMDL)	Relevance to Riverside County MS4 Permit and Status
Task 4	4.1 – Watershed-wide Nutrient Monitoring Plan(s)	TMDL responsible parties to submit collectively or individually a watershed-wide nutrient water quality monitoring program for Regional Board approval; submit modified program as needed	Initial plan due December 31, 2005; Revised plan due December 31, 2006 Annual report due by August 15 each year	Monitoring Program approved by Regional Board in March 2006 (Order R8-2006-0031); Amended monitoring program approved in March 2011 (Order R8-2011-0023; Annual reports submitted through August 25, 2011
	4.2 – Lake Elsinore Nutrient Monitoring Plan(s)	TMDL responsible parties to submit collectively or individually a Lake Elsinore in-lake nutrient water quality monitoring program for Regional Board approval; submit modified program as needed		
	4.3 – Canyon Lake Nutrient Monitoring Plan(s)	TMDL responsible parties to submit collectively or individually a Canyon Lake in-lake nutrient water quality monitoring program for Regional Board approval; submit modified program as		
Task 5	Agricultural Discharges – Nutrient Management Plan	Agricultural operators collectively or individually shall submit an NMP that addresses a range of agricultural-related activities	Plan/Schedule due September 30, 2007	Not applicable to MS4 dischargers; draft submitted; final plan due by December 31, 2011
Task 6	On-site Disposal System (Septic Systems) Management Plan	County of Riverside and Cities of Perris, Moreno Valley, and Murrieta shall submit collectively or individually a Septic System Management Plan	Dependent on State Board approval of relevant regulations	Relevant to the following MS4 Permittees; County of Riverside and the Cities of Perris, Moreno Valley and Murrieta; San Jacinto Onsite Wastewater Management Program report was submitted on November 17, 2007; implementation ongoing

Table A-1. TMDL Implementation Plan Tasks Applicable to MS4 Permittees (Continued)

Task No.	Task Name	Task Description	Compliance Date (per TMDL)	Relevance to Riverside County MS4 Permit and Status
Task 7	7.1 – Revision of Drainage Area Management Plan (DAMP)	Revise DAMP to include TMDL requirements	August 1, 2006, ff.	Revised DAMP July 24, 2006, as required by existing permit and TMDL. Entire DAMP revised again July 29, 2011.
	7.2 – Revision of the Water Quality Management Plan (WQMP)	Review WQMP to include TMDL requirements	August 1, 2006,ff.	Revised WQMP submitted July 24, 2006 approved by Order R8-2004-0080; Order R8-2005-0038 amended Order 01-34; additional revision to WQMP to comply with new MS4 permit (Order R8-2010-0033) submitted July 29, 2011; revised WQMP under Regional Board review
	7.3 – Update of the Caltrans Stormwater Management Plan (SWMP) and Regional Workplan	Revise SWMP annually as required; submit a Regional Workplan that includes plans and schedules for meeting TMDL requirements	August 1, 2006	Not applicable to MS4 dischargers; revisions to occur as part of permit renewal process
	7.4 – Update of US Air Force, March Air Reserve Base SWPPP	Revise facility SWPPP as needed to incorporate TMDL requirements	Dependent on nutrient monitoring program results	Not applicable to MS4 dischargers; revisions to occur as part of permit renewal process
Task 8	Forest Area – Review/Revision of Forest Service Management Plans	Submit for approval a plan with a schedule for the identification and implementation of Management Practices to reduce nutrients from Cleveland and San Bernardino National Forests	Plan/schedule due September 30, 2007	Not applicable to MS4 dischargers; considered complete – draft submitted to the Regional Board on September 27, 2007 that stated the existing Forest Plans are sufficient to meet TMDL requirements. Regional Board found the proposed plan and schedule for BMP implementation satisfies TMDL requirements
Task 9	Lake Elsinore In-Lake Sediment Nutrient Reduction Plan	TMDL responsible parties (including MS4 Permittees) to submit collectively or individually a proposed plan and schedule for in-lake sediment nutrient reduction that includes a monitoring program	Plan/schedule due March 31, 2007	Complete; implementation ongoing
Task 10	Canyon Lake In-Lake Sediment Treatment Evaluation	TMDL responsible parties (including MS4 Permittees) to submit collectively or individually a proposed plan and schedule for in-lake sediment nutrient reduction that includes a monitoring program	Plan/schedule due March 31, 2007	Complete

Table A-1. TMDL Implementation Plan Tasks Applicable to MS4 Permittees (Continued)

Task No.	Task Name	Task Description	Compliance Date (per TMDL)	Relevance to Riverside County MS4 Permit and Status
Task 11	Watershed and Canyon Lake and Lake Elsinore In-Lake Model Updates	TMDL responsible parties (including MS4 Permittees) to submit collectively or individually a proposed plan and schedule to update the existing Lake Elsinore/San Jacinto River Nutrient Watershed Model and the Canyon Lake and Lake Elsinore in-Lake models	Plan/schedule due March 31, 2007	Modeling efforts completed December 23, 2010 per June 30, 2011 RCFC&WCD letter to the Regional Board
Task 12	Pollutant Trading Plan or functional equivalent	TMDL responsible parties (including MS4 Permittees) to submit collectively or individually a proposed plan, schedule and funding strategy for project implementation, an approach for tracking pollutant credits and a schedule for reporting status of implementation	Plan/schedule due September 30, 2007	Initial plan/schedule for developing Pollutant Trading Plan has been submitted and approved; implementation on-going
Task 13	Review and Revise Nutrient Water Quality Objectives (WQOs)	For Canyon Lake and Lake Elsinore, the Regional Board will (a) review and revise as necessary the total inorganic nitrogen WQOs; and (b) evaluate the appropriateness of establishing total phosphorus and un-ionized ammonia WQOs	December 31, 2009	Regional Board action pending collection of additional data
Task 14	Review of TMDL/WLA/LA	Regional Board will re-evaluate basis for the TMDLs and implementation at least once every three years, and revise TMDL as needed	Once every 3 years	To date, TMDL has not been revised; the next triennial review is scheduled for 2015

A.4.3 Task 4 - Nutrient Water Quality Monitoring Program

Task 4 of the TMDL implementation plan requires the responsible jurisdictions to submit to the Regional Board for approval a proposed watershed-wide compliance monitoring program (Task 4.1) and in-lake compliance monitoring plans for Lake Elsinore (Task 4.2) and Canyon Lake (Task 4.3). The required Monitoring Program should include:

- A watershed-wide monitoring program to determine compliance with interim and/or final nitrogen and phosphorus allocations, and compliance with the nitrogen and phosphorus TMDL, including the waste load allocations (WLAs) and load allocations (LAs).
- A Lake Elsinore in-lake nutrient monitoring program to determine compliance with interim and final nitrogen, phosphorus, chlorophyll a, and dissolved oxygen numeric targets. In addition, this program will evaluate and determine the relationship between ammonia toxicity and the total nitrogen allocation to ensure that the total nitrogen allocation will prevent ammonia toxicity in Lake Elsinore.
- A Canyon Lake nutrient monitoring program to determine compliance with interim and final nitrogen, phosphorus, chlorophyll a, and dissolved oxygen numeric targets. In addition, the monitoring program will evaluate and determine the relationship between ammonia toxicity and the total nitrogen allocation to ensure that the total nitrogen allocation will prevent ammonia toxicity in Canyon Lake.

The Lake Elsinore & Canyon Lake Nutrient TMDL Monitoring Program was approved by the Regional Board March 3, 2006 (Order No. R8-2006-0031). The Task Force submitted a Quality Assurance Project Plan (QAPP), which was also approved by the Regional Board. All required activities have been carried out and Annual Reports prepared and submitted to the Regional Board by August 15th of each year.

The Lake Elsinore and San Jacinto Watershed Authority (LESJWA) on behalf of the Task Force submitted a revised in-lake monitoring program for Lake Elsinore and Canyon Lakes to the Regional Board on December 23, 2010. This proposal also provided a rationale for the deferral of a watershed-wide monitoring program pending development of the CNRP. The Regional Board approved the revised in-lake monitoring program and the request for deferral of the watershed-wide monitoring program to the CNRP (Order No. R8-2011-0023, March 4, 2011).

In a letter dated June 7, 2011 the Task Force requested that monitoring be reduced further to allow resources to be re-focused on project implementation in Canyon Lake. However, monitoring efforts would be restored in time to assess compliance with the 2015-16 interim targets. The Regional Board indicated by letter (September 2, 2011) that it may be supportive of further reductions in the monitoring program as long as the reductions are justified and that there are firm and certain commitments by the Task Force to move forward with specific in-lake and/or watershed projects. The Regional Board also stated that reductions in in-lake monitoring may be appropriate given the existing volume of lake data; however, reducing watershed monitoring is a concern given the need to assess compliance with the TMDL, WLAs and LAs. Regardless, the Regional Board agreed to work with the Task Force on the development of a revised monitoring program.

A.4.4 Task 6 - On-site Disposal Systems (Septic Systems) Management Plan

The TMDL implementation plan includes the following requirement, with regards to septic systems:

> "No later than 6 months after the effective date of an agreement between the County of Riverside and the Regional Board to implement regulations adopted pursuant to Water Code Sections 13290-13291.7, or if no such agreement is required or completed, within 12 months of the effective date of these regulations, the County of Riverside and the Cities of Perris, Moreno Valley and Murrieta shall, as a group, submit a Septic System Management Plan to identify and address nutrient discharges from septic systems within the San Jacinto watershed."

The latter approach, implementation of a Septic System Management Plan *(San Jacinto Onsite Wastewater Management Program)* was completed on November 17, 2007. This document establishes a general framework for an onsite wastewater management program, with the assumption that the various agencies involved will further refine their individual programs. Completion of this document satisfied the requirements of the TMDL Task; implementation of the plan is ongoing. The State Board is drafting new OWTS regulations that will enhance regulation of OWTS owners and require additional actions of local government agencies (including MS4 Permittees) with permitting powers over OWTS. Upon adoption of the policy, the MS4 Permittees will revise their programs as required.

A.4.5 Task 7.1 - Revision of Drainage Area Management Plan (DAMP)

The TMDL implementation plan required the MS4 Permittees to revise their DAMP to incorporate TMDL requirements by August 1, 2006. The MS4 program adopted a revised DAMP on July 24, 2006.

On January 29, 2010, the Regional Board adopted a new MS4 permit to authorize the discharge of urban runoff from MS4 facilities in Riverside County within the Santa Ana Region MS4 Permit area. This new permit requires additional updates to the DAMP as appropriate to incorporate interim water quality based effluent-limits established in the permit (Section VI.2.D.a, b). A revised DAMP was submitted to the Regional Board for approval on July 29, 2011 and is pending approval.

DAMP Section 13.4 (July 29, 2011 version) addresses the requirements of the Lake Elsinore/Canyon Lake TMDL. The DAMP includes the following TMDL-specific elements:

- Section 13.4.4.2 summarizes the Permittees' strategy for complying with the TMDL WLA assigned to the specified Permittees.
- Section 13.3 describes programmatic BMPs implemented by the Permittees to address TMDLs in the permitted area, including public education and outreach, inspection and enforcement actions taken by the Permittees. Section 13.4.4.2 and 13.4.4.3 describes the Permittees' participation in the TMDL Task Force and LESJWA, and their roles in assisting the Permittees in implementing TMDL implementation tasks.
- Section 13.4.4.5 describes how the Permittees propose to address BMP Effectiveness evaluations.
- Section 13.4.4.6 describes how the Permittees propose to conduct monitoring to determine compliance with Lake Elsinore and Canyon Lake Nutrient TMDL WLAs assigned to the Permittees.
- In addition to the compliance programs specified above, the Permittees also implement numerous compliance programs that manage nutrient discharges to Canyon Lake and Lake Elsinore. Section

13.4.4.3.2 of the DAMP summarizes these programs, which range from management of sanitary sewer overflows to ensuring appropriate BMP implementation for new development and redevelopment projects. Details regarding each of the summarized programs are provided in other sections of the DAMP.

The DAMP may require additional revision based on the outcome of the CNRP development and approval process. Specifically, the MS4 permit requires incorporation of relevant CNRP elements within 180 days after Regional Board approval of the CNRP.

A.4.6 Task 7.2 - Revision of the Water Quality Management Plan (WQMP)

The TMDL implementation plan required the MS4 Permittees to revise their WQMP (Appendix O of the DAMP) to incorporate TMDL requirements by August 1, 2006. The MS4 program adopted a revised WQMP on July 24, 2006.

On January 29, 2010, the Regional Board adopted a new MS4 permit to authorize the discharge of urban runoff from MS4 facilities in Riverside County within the Santa Ana Region MS4 Permit area. This new permit requires revision to the WQMP to not only incorporate LID-based BMP practices, but also, as appropriate, incorporate interim water quality based effluent-limits established in the permit (Section VI.2.D.a, b) and relevant CNRP elements.

The Riverside County MS4 program submitted a revised WQMP to the Regional Board on July 29, 2011; a final WQMP was submitted June 28, 2012 and was approved by the Regional Board on October 22, 2012. Additional revision of the WQMP may be required following approval of this CNRP. Specifically, the MS4 permit requires incorporation of relevant CNRP elements into the WQMP within 180 days after Regional Board approval of the CNRP.

A.4.7 Task 9 - Lake Elsinore In-Lake Sediment Nutrient Reduction Plan

The In-Lake Sediment Nutrient Reduction Plan, dated October 31, 2007, relies on existing projects that have been or are being implemented to improve the water quality in Lake Elsinore. These Phase 1 remediation projects include (a) stabilizing Lake Elsinore depth with recycled water; (2) reducing the carp population in Lake Elsinore through a fishery management program; and (3) installing and operating an aeration/mixing system in Lake Elsinore. The Regional Board approved this plan (Order No. R8-2007-0083) on November 30, 2007).

The October 31, 2007 plan included a preliminary list of other mitigation strategies (Phase 2 Alternatives) for potential implementation in the event that the three remediation strategies described above are not sufficient to achieve the in-lake numeric targets for Lake Elsinore. However, in a letter dated June 30, 2011 the Task Force indicated that the Phase 1 projects are performing as expected, and if continued, are likely to achieve the nutrient reductions required to comply with the WLAs and LAs in Lake Elsinore. In its response (September 2, 2011), the Regional stated that while it appears that the Phase 1 projects may be sufficient to reduce phosphorus levels in Lake Elsinore, that nitrogen and chlorophyll-a may not be controlled by the Phase 1 projects and further consideration of Phase 2 projects may be necessary.

A.4.8 Task 10 - Canyon Lake In-Lake Sediment Treatment Evaluation

Task 10 of the TMDL required completion of an in-lake sediment treatment evaluation plan for Canyon Lake. The Task Force submitted this plan to the Regional Board on June 25, 2007. The plan included an evaluation of alum treatment, aeration and hypolimnetic oxygenation system (HOS) as alternatives for in-lake sediment treatment in Canyon Lake, and a proposed plan for additional modeling and preparation of an implementation schedule. Regional Board Order No. R8-2007-0083 approved the plan and schedule for additional implementation activities.

In LESJWA's December 31, 2010 letter to the Regional Board, the Canyon Lake stakeholders indicated that it was considering two alternatives for nutrient control in Canyon Lake: (1) HOS; and (2) application of Phoslock. However, of these two alternatives, the letter indicated that the stakeholders believed that it would only be necessary to implement the HOS in order to achieve the response targets specified in the TMDL. In a May 17, 2011 meeting with the Regional Board, the Task Force discussed the proposed alternatives further in the context of implementation strategies: (a) Strategy A - use of alum, Phoslock or zeolite; and (b) Strategy B -implementation of HOS. The Task Force preferred Strategy B.

The Task Force completed a study titled *Canyon Lake Hypolimnetic Oxygenation System Preliminary Design Phase I Report i*n April 2011. The report evaluated multiple scenarios and identified a recommended design scenario. To facilitate continued planning for implementation of HOS, LESJWA submitted a letter to the Regional Board on June 7, 2011 requesting a formal response from Regional Board regarding the proposed strategies. In a letter dated September 2, 2011, the Regional Board indicated its support, as long as watershed improvements and nutrient reduction actions are also undertaken consistent with existing permit requirements and BMPs.

The December 31, 2011 draft of the CNRP contained an evaluation of different strategies for in-lake reduction of nutrient levels in Canyon Lake, and determined that HOS would be the most effective means of complying with the nutrient TMDL. The basis for this determination were studies showing that suppression of nutrient flux from lake bottom sediments by creating an oxic condition at the sediment water interface would more than offset the load reduction needed to reduce existing urban and septic loads to the allowable WLA/LAs, after accounting for estimated watershed loads reduction.

In January of 2012, the Task Force sought Michael Anderson to conduct additional studies to determine the potential impact of HOS on in-lake TMDL response targets for chlorophyll-a and DO and to evaluate chemical addition alternatives. The studies were intended to provide additional confirmation on the selection of a HOS by assessing whether it can be a whole-lake solution, or to revise the proposed in-lake nutrient management strategy to use chemical addition or regulatory approaches to achieve the response targets. Anderson 2012b determined that exceedences of the chlorophyll-a response target would continue to occur if only HOS were to be implemented in the lake. In its Mar 31, 2012 CNRP comment letter, the Regional Board states that if allocations are met by all dischargers, but in lake water quality response targets are not achieved, then the TMDL will be reconsidered and allocated loads may be further reduced.

Thus, the Permittees opted to prioritize in-lake BMPs based on their effectiveness in meeting the TMDL response targets for chlorophyll-a and DO. Adding alum to Canyon Lake was estimated to be highly effective in achieving the interim and final chlorophyll-a response target, therefore to control algae in the lake, the Permittees plan is to first conduct 5 alum applications over a 2-year period beginning in September 2013.

A.4.9 Task 11 - Watershed and Canyon Lake and Lake Elsinore In-Lake Model Updates

The Lake Elsinore and Canyon Lake TMDLs are based on watershed and in-lake water quality models (Lake Elsinore and Canyon Lake Nutrient Source Assessment –Final Report, January 2003). Task 11 requires an update of these models to consider additional data and information gathered from TMDL monitoring programs. The Task Force submitted a plan and schedule for updating these models to the Regional Board by letter dated October 31, 2007. The Regional Board subsequently issued its approval (Order No. R8-2007-0083, November 30, 2007).

The Task Force submitted the updated model *(San Jacinto Watershed Model update (2010) – Final,* October 7, 2010) and a spreadsheet tool for calculating the nutrient loads contributed by each TMDL responsible party to the Regional Board on December 23, 2010. Additional modeling needs were identified in the 2010 update. However, in its December 23, 2010 letter to the Regional Board, the Task Force stated rather than updating the model, resources would be more wisely spent on implementing in-lake projects to achieve the numeric response targets. This recommendation was reiterated in a June 30, 2011 letter to the Regional Board. The June 30, 2011 letter also indicated that the Task Force considers Task 11 to be complete.

The Regional Board's September 2, 2011 letter stated that in principle staff agreed that at this time resources should be expended on implementation activities rather than modeling. However, for the Regional Board to consider Task 11 complete, the following conditions should be met:

Funds earmarked or considered necessary for model update work are used to implement new remediation projects; these new projects do not include the Phase 1 projects already implemented in Lake Elsinore, though enhancements to those projects may be considered;

- The Task Force should explicitly acknowledge that it is its responsibility to conduct updates to the watershed model should (a) the spreadsheet tool proves insufficient to develop the CNRP; and/or (b) the Regional Board independently determines that updates to the model are necessary;
- The Task Force submits a proposed plan for update and use of the in-lake models; and
- If monitoring does not demonstrate TMDL compliance by December 31, 2015, then implementation efforts, including possible model updates, will need to be increased.

A.4.10 Task 12 - Pollutant Trading Plan (PTP)

Task 12 of the TMDL requires that a PTP be developed. On October 31, 2007 the Task Force submitted a plan and schedule outlining the steps for developing a pollutant trading plan. The Regional Board issued its approval in Order No. R8-2007-0083 (November 30, 2007). The Task Force plans to submit a PTP or its functional equivalent for Regional Board consideration, on an as needed basis, to support implementation of individual in-lake nutrient management projects.

Attachment B
Watershed Characterization

B.1 Introduction

Lake Elsinore and Canyon Lake lie within the San Jacinto Watershed, an area encompassing approximately 780 square miles in the San Jacinto River Basin. Located approximately 60 miles southeast of Los Angeles and 22 miles southwest of the City of Riverside, the San Jacinto Watershed lies primarily in Riverside County with a small portion located within Orange County.

The primary municipalities located in the San Jacinto River Basin include Lake Elsinore, Canyon Lake, Wildomar, Menifee, Perris, Moreno Valley, Hemet, San Jacinto, and Beaumont. Other jurisdictions include unincorporated Riverside County, March Air Force Base, U.S. National Forest lands, Wildlife Reserves, and Native American lands (Figure B-1,). Table B-1 summarizes the area covered by each jurisdiction.

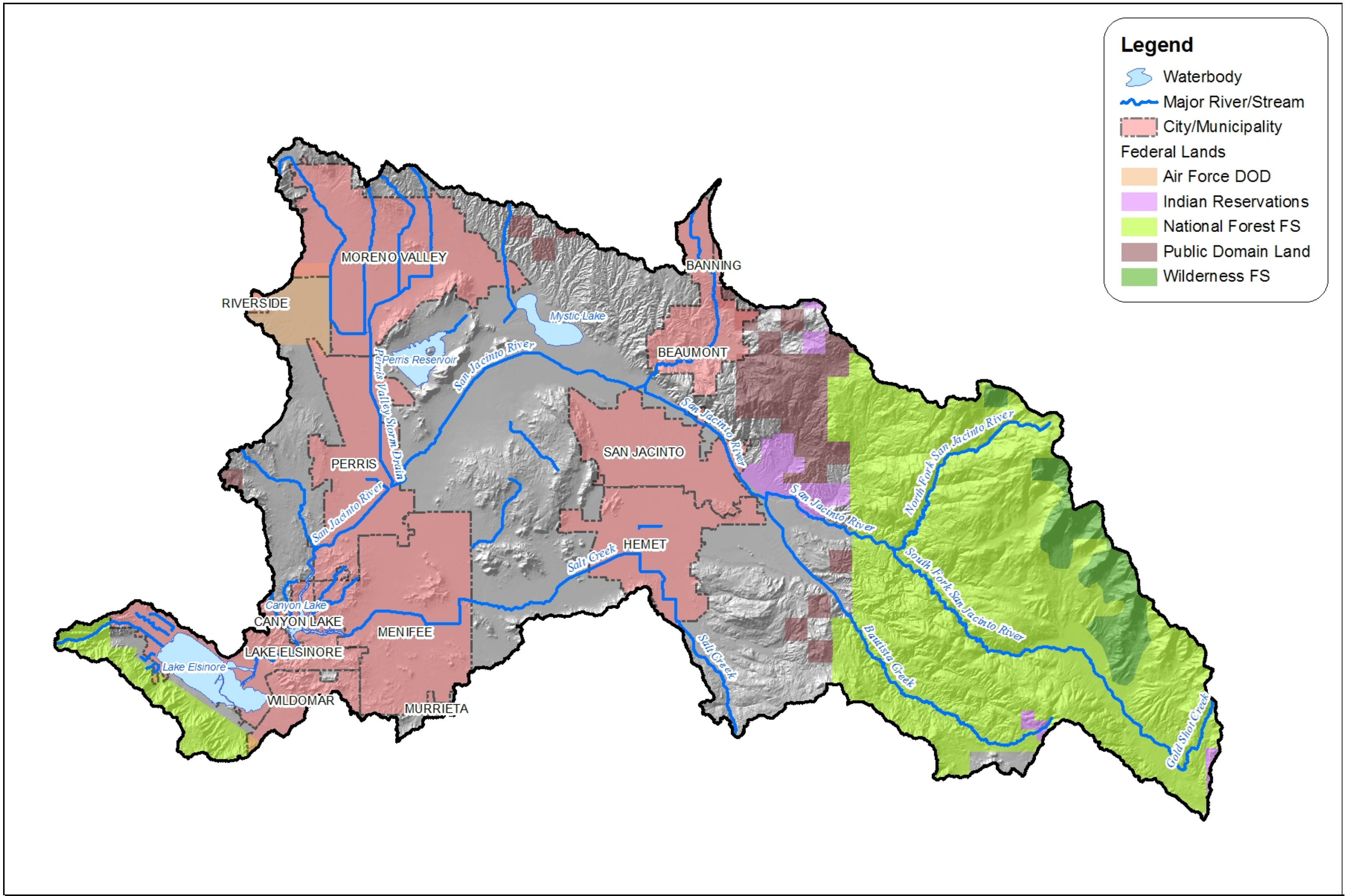
B.2 Land Use

The 2005 Southern California Association of Governments (SCAG) and the 2009 Western Riverside County Agriculture Coalition (WRCAC) land use data were used to characterize land use within the watershed. Where appropriate, land use data were consolidated into broader categories to help accurately support nutrient loading analyses (Table B-2, Figure B-2,). Tetra Tech (2010) provides additional information regarding land classification in the watershed.

Historically, land use development in the San Jacinto watershed has been associated with agricultural activities. However, over the past ten years land use has shifted markedly from agricultural-related to urban. This shift has influenced to a large degree the expected nutrient loading from various portions of the watershed. Although in the last few years the pace of urbanization has declined due to an economic downturn, continued shift from agriculture to urban land is expected to continue.

B.3 Climate

Area climate is characterized as semi-arid with dry warm to hot summers and mild winters. Average annual precipitation in Lake Elsinore/Canyon Lake area is approximately 11 inches occurring primarily as rain during winter and spring seasons (Table B-3). Precipitation in the upper watershed averages 18.7 inches annually. RCFC&WCD monitors precipitation at six rain gauges within the San Jacinto River Basin. Table B-4 lists the monitoring stations and average annual precipitation. Figure B-3 illustrates the location of these gauges.



Comprehensive Nutrient Reduction Plan For MS4 Permittees in Canyon Lake and Lake Elsinore Watershed

Dec. 1, 2011

0 2 4 8 Miles

Figure B-1

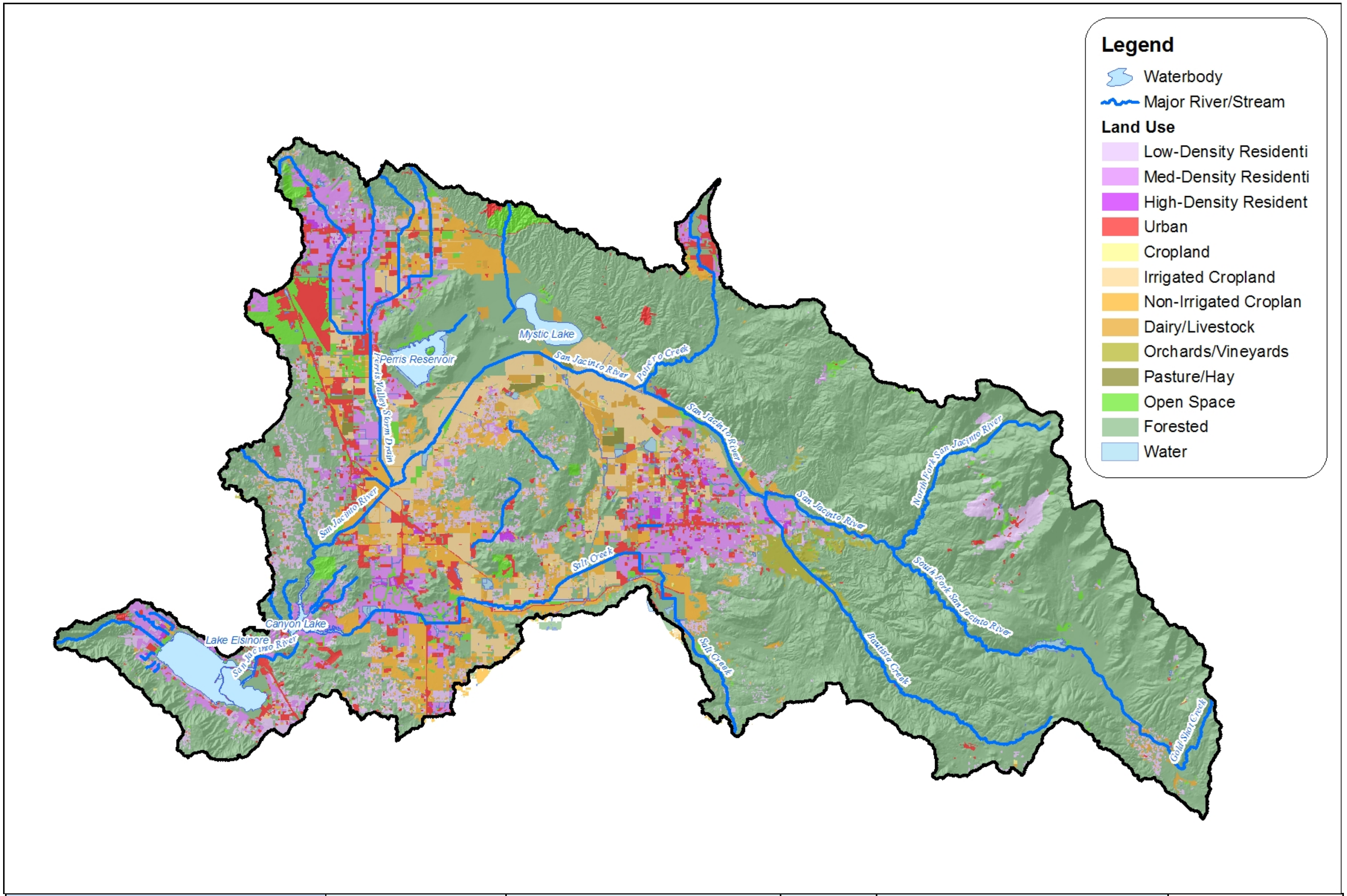
Cities, Districts, and Federal Lands in San Jacinto River Watershed

Table B-1. Area and Population for Jurisdictions Within the San Jacinto Watershed

Jurisdictions	Number of Acres	Percent of San Jacinto Watershed Area (%)	Approximate Population in SJR Watershed
Cities/County			
Riverside County	165,925	8.5	105,299
Moreno Valley	30,861	6.3%	188,636
Menifee	28,994	5.9%	71,012
Perris	20,277	4.1%	57,483
Hemet	17,306	3.5%	78,053
San Jacinto	16,132	3.3%	37,679
Lake Elsinore	14,949	3.0%	53,471
Beaumont	11,759	2.4%	9,639
Wildomar	5,080	1.0%	
Canyon Lake	2,969	0.6%	11,152
Murrieta	516	0.1%	
Riverside	511	0.1%	6,360
Banning	351	0.1%	
Other Jurisdictions			
U.S. National Forest	130,502	26.6%	
Public Domain Land BLM	18,716	3.8%	
Wilderness Lands	12,501	2.5%	
Indian Reservations BIA	7,130	1.5%	
Air Force DOD	5,875	1.2%	
Grand Total	490,354	100%	

Table B-2 Land Use Acreage Among San Jacinto River Basin Jurisdictions (source: 2010 Watershed Model Report)

Jurisdiction	**Urban**	**Low-Density Residential**	**Med-Density Residential**	**High-Density Resident**	**Cropland**	**Irrigated Cropland**	**Non-Irrigated Cropland**	**Dairy/ Livestock**	**Orchards/ Vineyards**	**Pasture/Hay**	**Open Space**	**Forested**	**Water**	**Grand Total**
Cities/County														
Banning	58	4	144	17			0				50	78		351
Beaumont	738	39	504	35			444	0	18		29	9,954		11,759
Canyon Lake	75	66	1,230	17			6	9			142	955	470	2,969
Hemet	2,666	560	4,371	632	36	1,299	2,117	511	21		674	4,114	304	17,306
Lake Elsinore	1,649	339	2,166	145	3	0	69		18		273	7,198	3,096	14,954
Menifee	3,304	3,512	4,825	294	199	1,232	5,971	746	210		1,640	6,419	640	28,994
Moreno Valley	3,341	2,245	8,520	340	56	1,862	4,388	200	261		953	8,297	398	30,861
Murrieta	152	16	203	14	1		54	10			7	47	11	516
Perris	2,925	1,055	2,056	154	49	3,269	2,710	50	144	327	2,151	4,917	470	20,277
Riverside	39		459								13			511
San Jacinto	1,617	489	1,951	169	83	4,266	757	1,737	99	339	466	3,647	513	16,132
Wildomar	480	1,346	532		2	32	84	7	32		31	2,539		5,083
Riverside County	3,406	12,891	3,640	328	580	14,926	7,488	4,360	3,898	459	4,811	104,903	4,235	165,925
Other Jurisdictions														
Air Force DOD	2,685		426				0				2,590	117	56	5,875
Indian Reservations BIA	77	222				35	325	3	102		42	6,239	83	7,130
U.S. National Forest	418	4,152	327		46	10	3	633	252		861	123,327	475	130,502
Public Domain Land BLM	26	62	66		5	36	18	2	44		590	17,868		18,716
Wilderness Lands	2	16						0			24	12,459		12,501
Grand Total	23,537	27,043	31,243	2,142	1,077	27,254	25,145	8,343	5,100	1,130	14,226	313,357	10,751	490,346
Land Use Percentage	4.8	5.5	6.4	0.4	0.2	5.6	5.1	1.7	1.0	0.2	2.9	63.9	2.2	



Comprehensive Nutrient Reduction Plan For MS4 Permittees in Canyon Lake and Lake Elsinore Watershed

Dec. 1, 2011

Figure B-2

Map of Watershed Categorized Land Uses

CDM

Table B-3 Average Monthly Temperatures and Precipitation

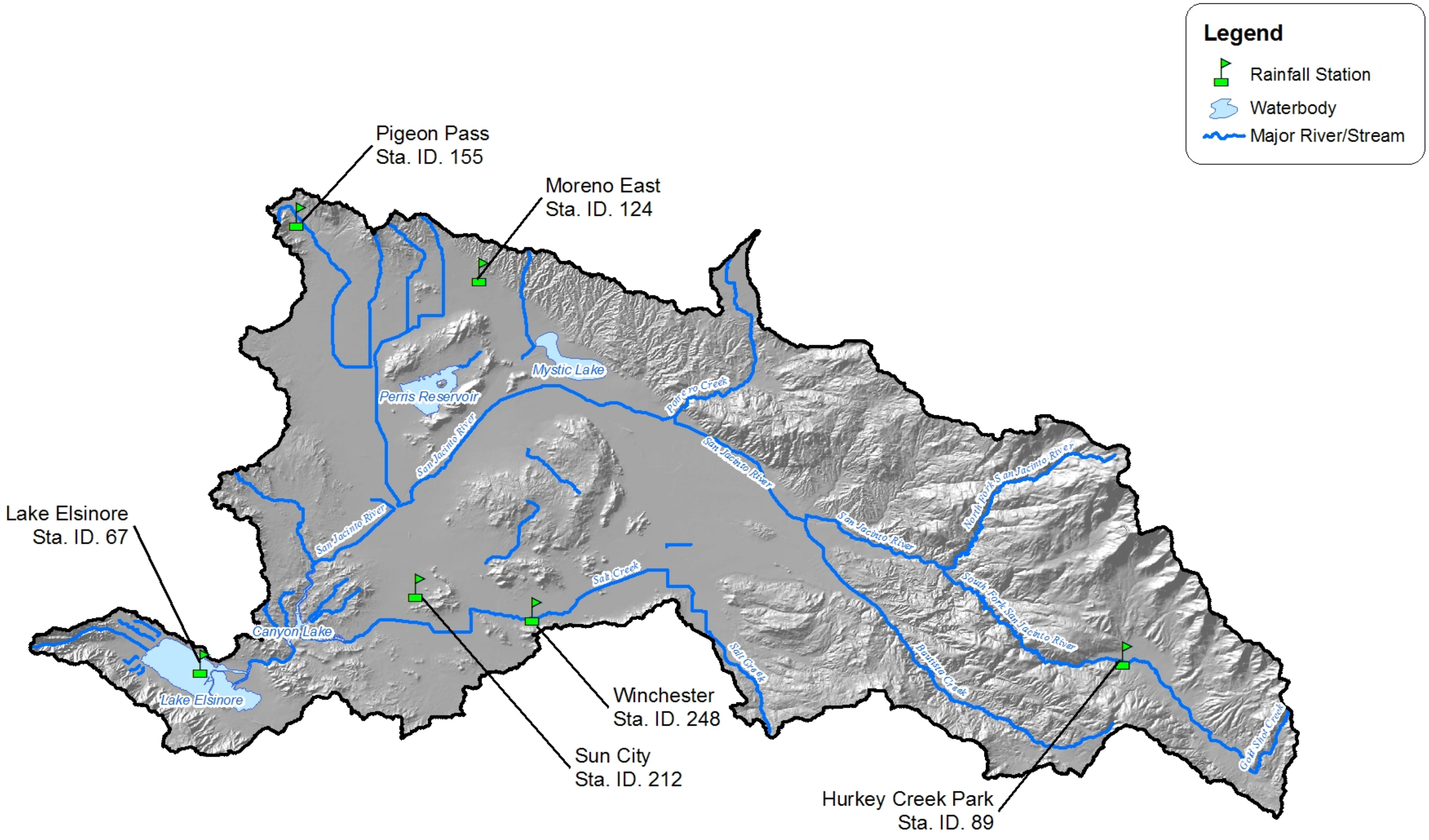
Month	Average Monthly Precipitation (in)	Average Monthly High Temperature (°F)	Average Monthly Low Temperature (°F)	Average Monthly Temperature (°F)
January	2.8	66	38	52
February	2.96	68	40	54
March	2.29	71	43	57
April	0.56	77	46	62
May	0.22	83	51	67
June	0.02	91	56	74
July	0.1	98	61	80
August	0.12	98	62	80
September	0.3	93	58	76
October	0.36	84	51	67
November	0.78	73	42	58
December	1.58	67	37	52
Annual	12.09	81	49	65

Source: Monthly Average for Lake Elsinore, CA - weather.com
http://www.weather.com/weather/wxclimatology/monthly/USCA0580

Table B-4 Precipitation Monitoring Stations in San Jacinto Watershed

Station code	Agency	Station Name	Period of Record Collected	Annual Rainfall (inches)
67	RCFC&WCD	Elsinore	7/1/1990 –7/31/2009	10.6
212	RCFC&WCD	Sun City	7/1/1990 –7/31/2009	11.2
155	RCFC&WCD	Pigeon Pass	7/1/1990 –7/31/2009	12.8
124	RCFC&WCD	Moreno East	7/1/1990 –7/31/2009	12.1
248	RCFC&WCD	Winchester	7/1/1990 –7/31/2009	10.8
89	RCFC&WCD	Hurkey Creek Park	7/1/1990 –7/31/2009	18.7

Source: Tetra Tech Inc., San Jacinto Watershed Model Update, October, 2010



Comprehensive Nutrient Reduction Plan For MS4 Permittees in Canyon Lake and Lake Elsinore Watershed	Dec. 1, 2011	0 2 4 8 Miles	**Figure B-3**	CDM
	Map of Precipitation Gauges			

B.4 Hydrology

This section presents the hydrologic characteristics for the watershed draining to Canyon Lake and Lake Elsinore. The north fork and south fork San Jacinto River are located in the upper portions of the watershed where they converge and collectively become the San Jacinto River upstream of Mystic Lake (Figure B-4). Overflow from Mystic Lake is conveyed by the San Jacinto River to Canyon Lake. Canyon Lake is formed by Canyon Lake Dam; water releases from Canyon Lake ultimately drain to the downstream Lake Elsinore.

All streams in the San Jacinto River watershed are ephemeral. Under normal dry periods, the mainstream of the San Jacinto River is dry, contributing no flow to Canyon Lake, and upstream pollutants do not reach the lakes. External sources contribute nutrients to the lakes via storm flows only during the wet season (October, through April). Further information regarding the hydrologic scenario evaluation is discussed in the Lake Elsinore and Canyon Lake TMDL.

Due to the ephemeral nature of the San Jacinto River system, the location of the various land use sources within the watershed is a major factor affecting the ultimate delivery of nutrients to Canyon Lake and Lake Elsinore. A natural sump, formed by the confluence of two faults, known as Mystic Lake, serves as a hydrologic barrier between the upper and lower San Jacinto Watershed. Mystic Lake is located north of Ramona Expressway and east of the City of Moreno Valley in the San Jacinto Wildlife Preserve. This sump is gradually subsiding providing more runoff storage capacity over time.

During dry hydrologic seasons, Lake Elsinore and Canyon Lake only receive runoff from the subwatersheds directly tributary to them. For example, Lake Elsinore would only receive runoff from the local watershed downstream of Canyon Lake. Similarly, Canyon Lake would only receive runoff from the watershed areas downstream of Mystic Lake. Under moderate hydrologic years, Canyon Lake would be expected to spill, resulting in urban development and agricultural land practices in the central portion of the San Jacinto River watershed below Mystic Lake (including Perris Valley and the Salt Creek sub-watershed) additionally impacting water quality of Lake Elsinore. Lastly, during wet hydrologic years, heavy rain and/or extended periods of rainfall may exceed the storage capacity of Mystic Lake, causing surface flow from open space areas in the headwaters, stormwater runoff from portions of the cities of Hemet and San Jacinto draining to Zones 7-9, and agricultural runoff upstream of Mystic Lake, to reach Canyon Lake. Further, if the rainfall is significant, Canyon Lake may overflow into Lake Elsinore.

Major tributaries to the San Jacinto River include the Perris Valley storm drain and Salt Creek. Perris Valley storm drain conveys flows from the northern portion of the watershed to the San Jacinto River, between Mystic Lake and Canyon Lake. Salt Creek drains to Canyon Lake from the southeast. The U.S. Geological Survey (USGS) operates several flow gauges in the watershed (Table B-5, Figure B-4,), which provide the hydrologic data that were used in the development of the TMDL. The following subsections provide more detailed information regarding the hydrology of the watershed.

Table B-5 USGS Flow Gauge Stations in the San Jacinto Watershed

Station Number	Station Name	Historical Record
11070500	San Jacinto River near Elsinore, CA	1/1/1916–present
11070365	San Jacinto River near Sun City, CA	8/25/2000–present
11070270	Perris Valley Storm Drain at Nuevo Rd. near Perris,	10/1/1969–9/30/1997; 10/1/1998–present
11070210	San Jacinto River at Ramona Expressway near	8/23/2000–9/30/2010
11069500	San Jacinto River near San Jacinto, CA	10/1/1920–9/30/1991; 10/1/1996–present
11070465	Salt Creek at Murrieta Rd. near Sun City, CA	10/1/1983–9/30/1985; 10/1/2000–present

Representative Hydrologic Flow Scenarios

Hydrologic flow scenarios were developed in the Lake Elsinore and Canyon Lake Nutrient Total Maximum Daily Loads (TMDL) (California Regional Water Quality Control Board, 2004) to classify hydrologic conditions within the San Jacinto Watershed. Three scenarios (wet, moderate, and dry) were developed in the Lake Elsinore and Canyon Lake TMDL to evaluate the variability of nutrient loading to the lake due to the various hydrologic conditions that occur in the San Jacinto watershed. Representative years from 1991 – 2000 were initially chosen to represent various hydrologic conditions, and are described in Table B-6. Under wet conditions, the main stem of the San Jacinto River flows into and fills Mystic Lake, which then spills to Canyon Lake. Canyon Lake also spills to Lake Elsinore, and depending on the existing elevation, Lake Elsinore could fill and spill to Temescal Wash. The moderate condition is when the main stem of the San Jacinto River doesn't flow all the way to Canyon Lake, with flows from Salt Creek and the Perris Valley Storm Drain making up the water to Canyon Lake. However, Canyon Lake may have moderate spills to Lake Elsinore. Under dry conditions, the flow from the San Jacinto River watershed never reaches Lake Elsinore, with external nutrient loads to the lake coming from the runoff from the local watershed surrounding the lake.

Table B-6. Three hydrologic conditions defined in the TMDL

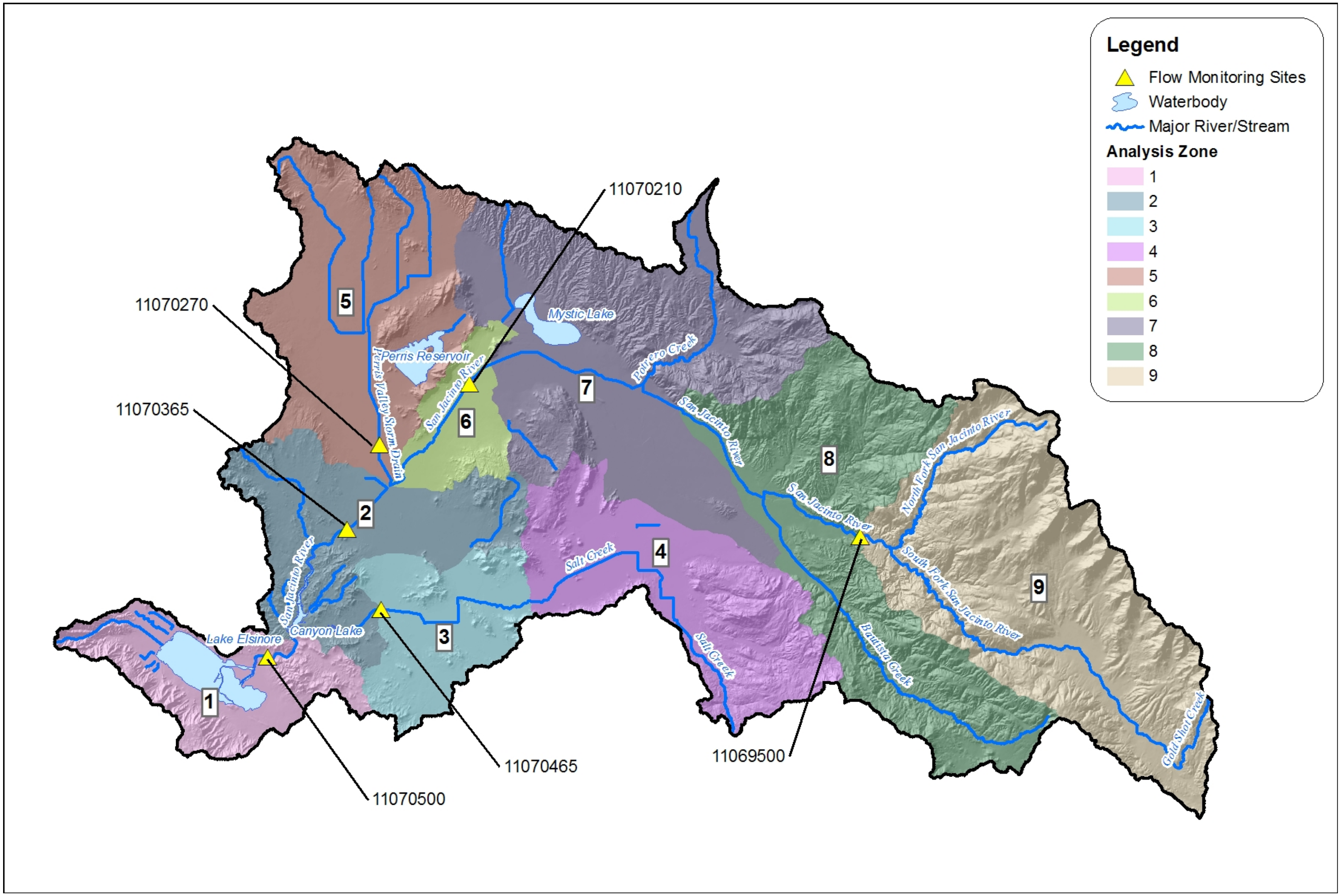
Scenario	Hydrologic Condition	Representative Water Year	Description
I	Wet	1998	Both Canyon Lake and Mystic Lake overflow; flow at the USGS gauging station 11070500 was 17,000 acre-feet
II	Moderate	1994	No Mystic Lake overflow; Canyon Lake overflowed, flow at the USGS gauging station 11070500 was 2,485 acre-feet
III	Dry	2000	No overflows from Mystic Lake or Canyon Lake, flow at the USGS gauging station 11070500 was 371 acre-feet

The relative flow frequency of each of the scenarios was determined using the annual total flow data (for each water year) at the USGS gauging station #1170500. Table B-7 lists the relative flow frequency of the wet, moderate and dry seasons.

Table B-7. Relative flow frequency at the USGS gauging station #1170500 during 1917 – 2011 period

Hydrologic Scenario (Category)	Years in Each Category	Relative Frequency (%) [1]
Wet	15	16%
Moderate	43	45%
Dry	37	39%

1) Frequency weighting in TMDL is based on 1917-2003 period of record and therefore results are slightly different than shown above



Comprehensive Nutrient Reduction Plan For MS4 Permittees in Canyon Lake and Lake Elsinore Watershed

Dec. 1, 2011

0 2 4 8 Miles

Figure B-4

Watershed Analysis Zones and Flow Monitoring Stations

B.4.1 Watershed Analysis Zones

As part of the development the TMDL model, the San Jacinto River Basin was divided into nine watershed analysis zones (Figure B-4). The delineation of these zones was based upon hydrologic features such as significant water retention features or major tributaries:

- Zones 7, 8, and 9, which drain to Mystic Lake, represent the most upstream portion of the watershed;
- Zone 6 represents the area downstream of Mystic Lake that drains directly to the San Jacinto River;
- Zone 5 drains to the Perris Valley Storm Drain which confluences with the San Jacinto River between Mystic Lake and Canyon Lake;
- Zones 3 and 4 drain to Salt Creek, which drains to Canyon Lake;
- Zone 2 drains the area downstream of the Perris Valley Storm Drain drainage area and drains to Canyon Lake; and
- Zone 1 represents that area that drains directly to Lake Elsinore.

B.4.2 Major Waterbodies

Lake Elsinore

Lake Elsinore is located in the southwest portion of the San Jacinto River Basin at the terminus of the San Jacinto River watershed. Lake Elsinore is a natural lake, which has been in existence for thousands of years. Prior to development in the area, the lake naturally experienced significant variations in lake level from being a dry lake bed to filling temporarily following extreme rain events. Today, the lake receives surface flows from local tributaries (Zone 1), which make up less than 10 percent of the overall San Jacinto River watershed and water releases from Canyon Lake. During rare overflow events, at approximately 1,255 feet water surface elevation, Lake Elsinore overflows into Temescal Creek and ultimately to the Santa Ana River.

Canyon Lake

Canyon Lake Reservoir was created in 1928 with the construction of the Railroad Canyon Dam. Over 90 percent of the San Jacinto watershed drains to Canyon Lake. Flows typically enter the reservoir from both the upper San Jacinto River watershed (Zones 5 and 6) and the Salt Creek watershed (Zones 3 and 4). Flows may also reach Canyon Lake from Zones 7-9 during rare periods when Mystic Lake overflows. The elevation of Canyon Lake Dam spillway is approximately 1,382 feet; when the lake level reaches this point flows continue downstream to Lake Elsinore. USGS flow gauge 11070500, located on the San Jacinto River downstream of Canyon Lake, has been in operation since 1916. During its operational period, it is estimated that flows from Canyon Lake have occurred 38 of the 94 years or a frequency of 40 percent.

Mystic Lake

Flows entering the San Jacinto River from upstream portions of the watershed (Zones 7-9) drain into Mystic Lake. Mystic Lake is typically a dry lake and serves as a water sink because flows entering the lake are generally lost from the system due to soil infiltration and evaporation. Mystic Lake is formed by the confluence of two faults and is located north of Ramona Expressway and east of the City of Moreno Valley in the San Jacinto Wildlife Preserve. This sump is gradually subsiding providing more runoff storage capacity over time. During high or long duration flow events, the storage capacity of Mystic Lake may be exceeded and overflow back to the San Jacinto River and downstream to Canyon Lake. Overflow at Mystic Lake occurs when the water surface elevation is approximately 1,425 feet. USGS flow gauge 11070210 is located on the San Jacinto River roughly 3.5 miles downstream of Mystic Lake. This gauge was in operation between 8/23/2000–9/30/2010 and records local runoff as well as overflows from Mystic Lake. Flow was recorded at Ramona Expressway in 2005, however field investigations determined the flow was from the local watershed area and not Mystic Lake. Given the low flow rates during the other years, it is assumed that since 2000, Mystic Lake has not overflowed.

Lake Hemet

Lake Hemet was created when Hemet Dam was constructed in 1895. The dam is owned and operated by the Lake Hemet Municipal Water District (LHMWD) and is a water source for the cities of Hemet and San Jacinto, and the San Jacinto Mountain community of Garner Valley. The lake is approximately 4,340 ft above sea level and located in the San Jacinto Mountains. The lake volume is roughly 8,100 acre-ft and the outlet flows to the south fork of the San Jacinto River. Flow data at USGS flow gage 11069500, located downstream of Lake Hemet, indicates that this area generally sustains baseflow after a rain event throughout the year. This is in contrast to flow data recorded at other gauges in the San Jacinto River Basin.

San Jacinto River

The headwaters of the San Jacinto River begin in the San Bernardino National Forest where the north and south forks converge east of Valle Vista. The San Jacinto River drains the upper portions of the San Jacinto River Basin to Mystic Lake. The river continues downstream of Mystic Lake to Canyon Lake and again downstream of the Canyon Lake Dam to Lake Elsinore where it terminates. The San Jacinto River Basin is a complex hydraulic system which includes hydraulic sinks, little or no sustained baseflow in most areas especially during dry periods, deep groundwater losses, and reduction in groundwater levels due to excessive groundwater pumping and limited recharge. Generally, the San Jacinto River is not sustained by groundwater flows during dry years and remains waterless. With limited surface water recharge from groundwater, water that infiltrates into the ground is considered to be lost from the system.

Perris Valley Storm Drain

The northwest area of the San Jacinto River watershed is drained by Perris Valley Storm Drain. The drain has its confluences with the San Jacinto River upstream of Canyon Lake. USGS gauge 11070270 is located on the Perris Valley Storm Drain near Perris, CA. Flows recorded at this gauge display high peak flow rates of short durations, a pattern commonly seen with stormwater runoff from developed areas with little or no associated groundwater flow.

Salt Creek

Salt Creek is an intermittent creek that drains southern portions of the San Jacinto River watershed. The drainage enters Canyon Lake from the southeast. USGS gauge 11070465 measures flow in Salt Creek near Sun City and displays a lower unit-area flow than other gauges in the watershed. However, the USGS rates the data recorded at this station as poor quality.

B.4.3 Flow

Wet weather runoff is the primary influence on flow rates observed in the San Jacinto watershed. Figure B-5 presents a flow duration curve for daily mean discharges at the USGS gauges (See Table B-5). The figure shows the cumulative-frequency curves, which represent the likelihood that a particular flow discharge is equaled or exceeded at the site. Figure B-5 indicates that the upstream portion of the San Jacinto River has a more stable flow rate, which suggests that this area receives groundwater inflow and snowmelt runoff that tends to infiltrate prior to reaching the Ramona Expressway gauge.

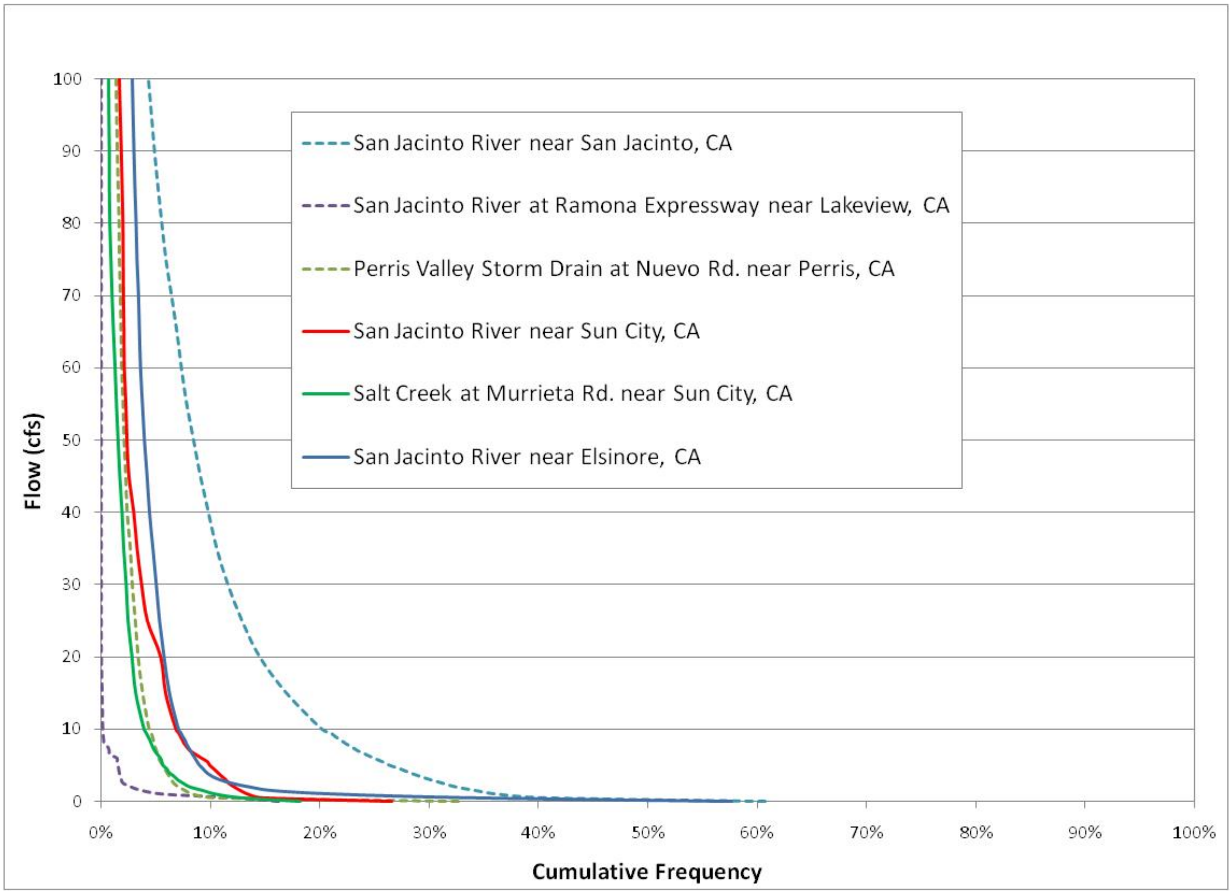
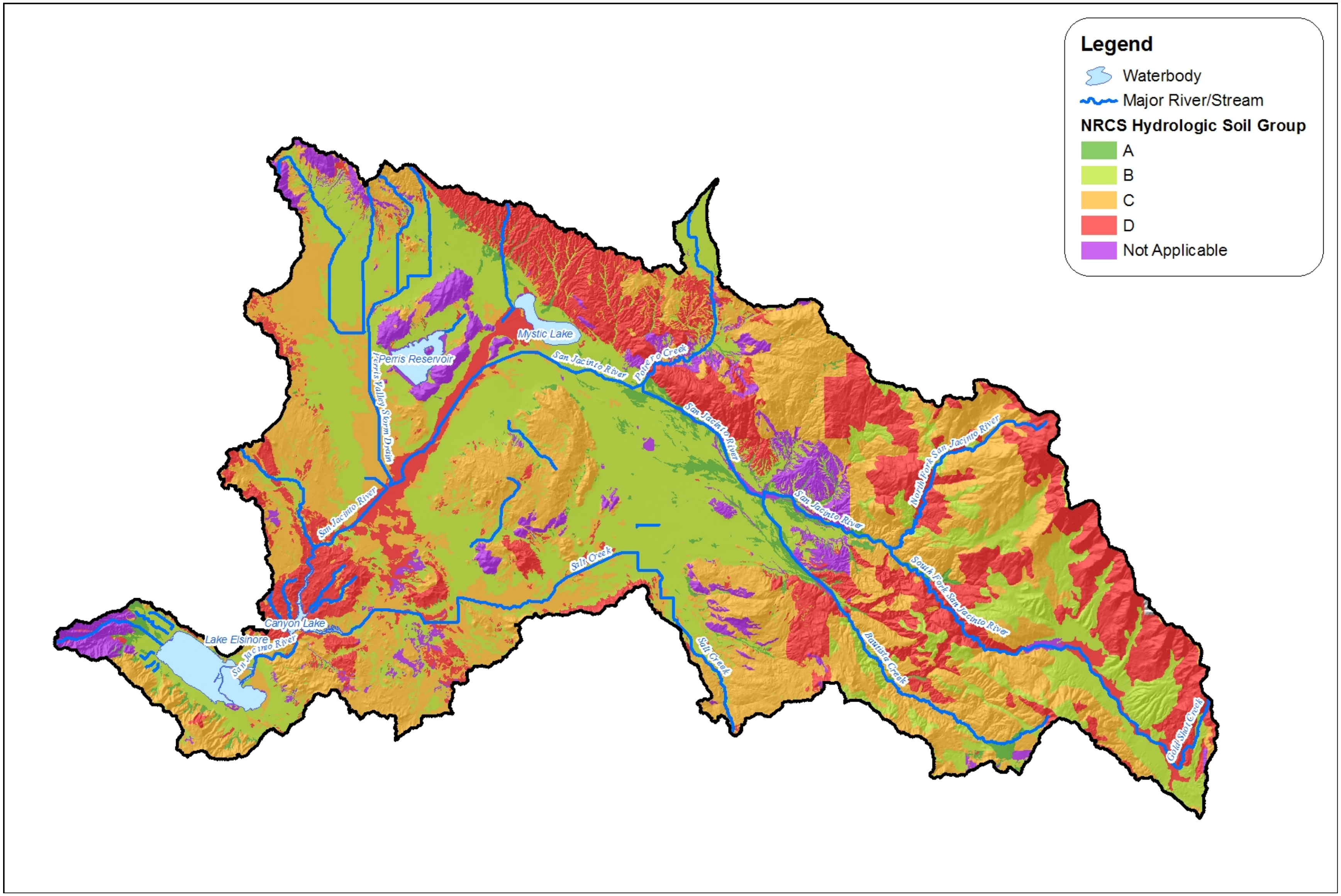


Figure B-5
Flow Duration Curves for Daily Mean Discharges at USGS Gauges in the San Jacinto River Watershed

B.4.4 Soils

The U.S. Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) categorizes soils into four distinct hydrologic soil groups, based on infiltration and transmission rates after prolonged wetting (Table B-8). Generally, soils in group A are well-drained and have a high infiltration while soils in group D have a slow infiltration rate. Soil data for the San Jacinto River Basin was obtained from STATSGO2 (USDA 2006) and summarized by hydrologic soil groups (Figure B-6). Areas draining to the north and south fork San Jacinto River are dominated by soil group C. Forest land is the most common land use in these areas. Areas draining to Salt Creek are also mainly represented by soil group C but differ from the north and south fork San Jacinto River drainage areas mainly because the unit-area flow for this area is lower. Potential causes for this difference may be poor quality of flow records, flows captured by the Paloma Valley Reservoir, or occasional diversions for irrigation and domestic use. The majority of the area draining to Perris Valley Storm Drain is classified as soil group B meaning the soil has moderate infiltration rates and a moderate rate of water transmission. This is a mixed land use area of the watershed and representative hydrographs show large stormwater runoff peaks with little or no associated groundwater flow. Local watersheds draining into Canyon Lake are classified as soil group D representing areas of low permeability.



Comprehensive Nutrient Reduction Plan For MS4 Permittees in Canyon Lake and Lake Elsinore Watershed

Dec. 1, 2011

0 2 4 8 Miles

Figure B-6

NRCS Hydrologic Soil Type

CDM

Table B-8. Hydrologic Soil Group Descriptions (USDA 2006)

Hydrologic Soils Group	Description
A	Soils with high infiltration rates. Usually deep, well drained sands or gravels. Little runoff.
B	Soils with moderate infiltration rates. Usually moderately deep, moderately well drained soils.
C	Soils with slow infiltration rates. Soils with finer textures and slow water movement.
D	Soils with very slow infiltration rates. Soils with high clay content and poor drainage. High amounts of runoff.
Not Applicable	Limited soil, exposed bedrock, or water body.

B.4.5 Water Quality

The following sections characterize water quality in Lake Elsinore, Canyon Lake, and runoff from the San Jacinto watershed. This analysis focuses on the primary indicators of nutrient impacts to water quality: total phosphorus, total nitrogen, dissolved oxygen, and chlorophyll *a*. This section is a summary of detailed information, which can be obtained Lake Elsinore & Canyon Lake Nutrient TMDL Annual Water Quality Reports, (http://www.sawpa.org/AnnualWQReports.htm).

Lake Elsinore

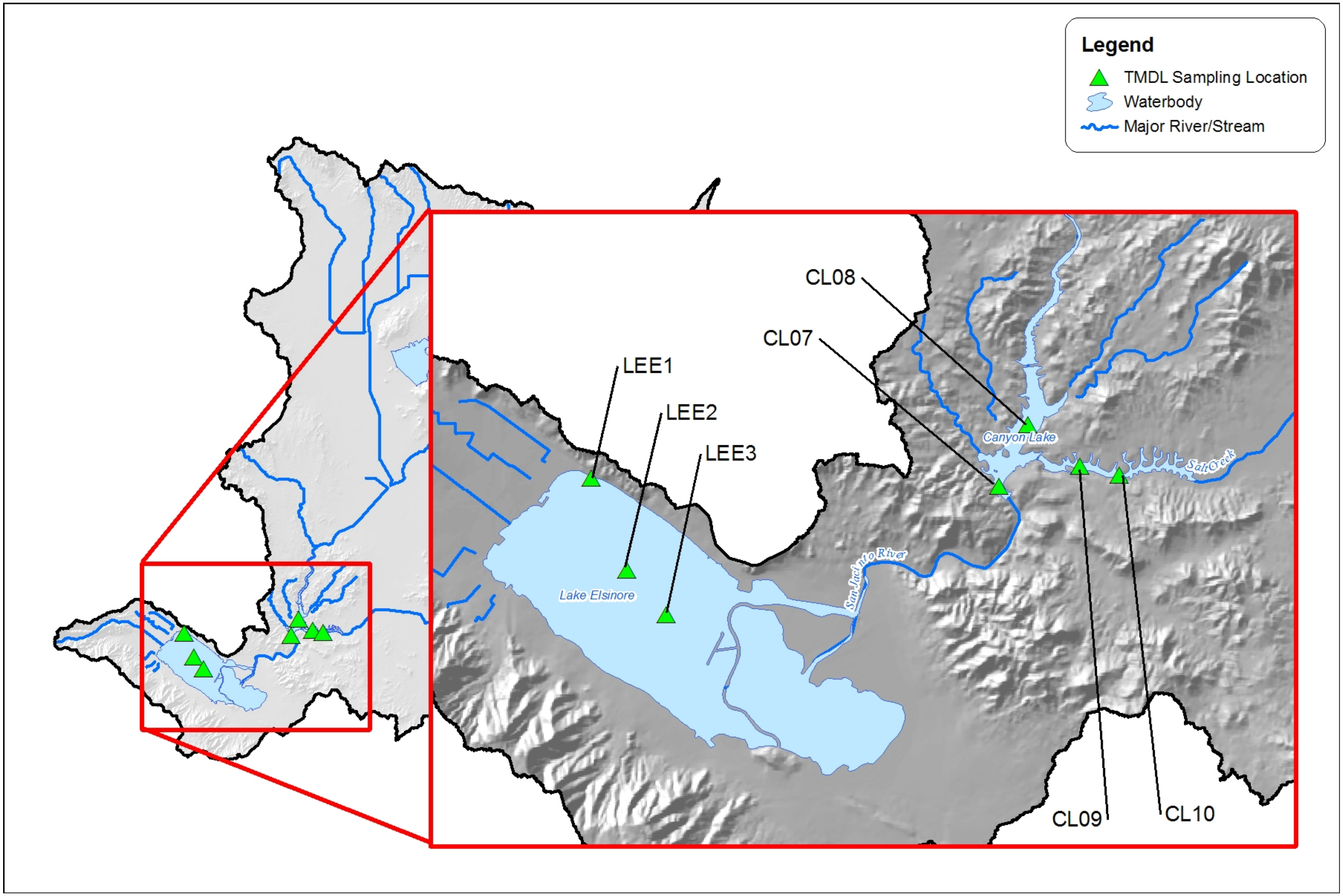
Elsinore Valley Municipal Water District's (EVMWD) initiated its NPDES compliance monitoring program for Lake Elsinore in April 2006. Initially, monitoring for nutrients occurred at three water quality sampling stations. Figure B-7 shows the sampling stations where surface, bottom, and integrated samples were collected. EMVWD collects samples monthly from October through May and biweekly from June through September.

Table B-9 summarizes monitoring results for the period July 1, 2006 through June 30, 2011 for the LEE2 sample location. Results are compared to basin plan objectives and TMDL targets.

Figure B-8 shows lake surface, integrated, and lake bottom dissolved oxygen concentrations observed at station LEE2. Summer months exhibit stratified dissolved oxygen, with the lake bottom samples declining to 0 mg/L. The winter months exhibit greater uniformity in dissolved oxygen concentrations, due to turnover and mixing of the epilimnion and hypolimnion.

Figure B-9 shows depth integrated total nitrogen and phosphorus results locations, averaged from all three sites. Nitrogen and phosphorus concentrations were generally uniform and did not exhibit seasonal fluctuations or significant changes as a result of depth. A spike in phosphorus concentrations was observed on April 11, 2011.

Figure B-10 shows depth integrated chlorophyll *a*, averaged from all three sites. There has been a gradual increase in chlorophyll *a* after October 2009, although further study is required to determine if this is a significant trend. Table B-10 provides the average chlorophyll *a* concentrations consolidated by season; concentrations decrease during the spring sample period compared to the other seasons, possibly due to an increase in precipitation which may dilute the algae.



Comprehensive Nutrient Reduction Plan For MS4 Permittees in Canyon Lake and Lake Elsinore Watershed

Dec. 1, 2011

0 2 4 8 Miles

Figure B-7

Lake Water Quality Monitoring Sites

CDM

Table B-9 Summary - Lake Elsinore Water Quality Data

Parameter	TMDL Compliance Date	Basin Plan Objectives or TMDL Targets	2006 - 2011 Results				
			No. of Sampling Events	Range of Daily Averages	Annual Mean	Annual Median	Standard Deviation
Dissolved Oxygen (mg/L) (Station LEE2, depth profile)	2015	Not less than 5 mg/L as a depth average	91	0.3 - 11.65	6.35	6.20	2.02
	2020	Not less than 5 mg/L 1 meter above lake bottom	91	0.00 - 11.50	4.24	3.65	2.56
pH (3 stations, depth profile)	---	6-5 - 8.5	101	6.72 - 9.76	8.92	8.95	0.35
Ammonia N (NH4-N) (mg/L) (3 stations, integrated samples)	2020	Data Results	100	ND - 0.77	0.14	0.09	0.15
		Acute Criteria Compliance	No observed exceedances of the acute criterion at the range of pH conditions measured.				
		Chronic Criteria Compliance	Exceedance of the chronic criteria observed 7.2% of the time (80 out of 1040 ammonia readings).on the following dates: 8/29/06, 12/19/06, 1/10/07, 10/12/07, 11/28/07, 1/16/08, 5/16/08, 6/27/08, 9/18/08, 7/29/09, 8/19/09 , 8/26/09, 9/11/09, 9/25/09, 10/21/09, 12/4/09, 6/9/10, 7/23/2010, 8/18/2010, 9/30/2010, 10/12/2010, and 6/29/2011.				
Total Nitrogen (TN) (mg/L) (3 stations, integrated samples)	2020	Annual average 0.75 mg/L	90	0.50 - 8.56	3.57	3.29	1.42
Total Phosphorus (TP) (mg/L) (3 stations, integrated samples)	2020	Annual average 0.1 mg/L	81	0.09 - 0.89	0.23	0.20	0.12
Chlorophyll *a* (µg/L) (3 stations, surface samples 0-2 m, April to September)	2015	Summer average no greater than 40 µg/L	95	15.2 - 247.5	93.27	88.37	55.08
Chlorophyll *a* (µg/L) (3 stations, integrated samples, April to September)	2020	Summer average no greater than 25 µg/L	96	16.1 - 271.3	89.41	90.19	52.51
Secchi Depth (cm) (3 stations)	---	---	100	28 - 102	57.56	52.19	19.64
Total Dissolved Solids (mg/L) (3 stations, integrated samples)	---	2000 mg/L	101	1082 - 1967	1449	1437	205

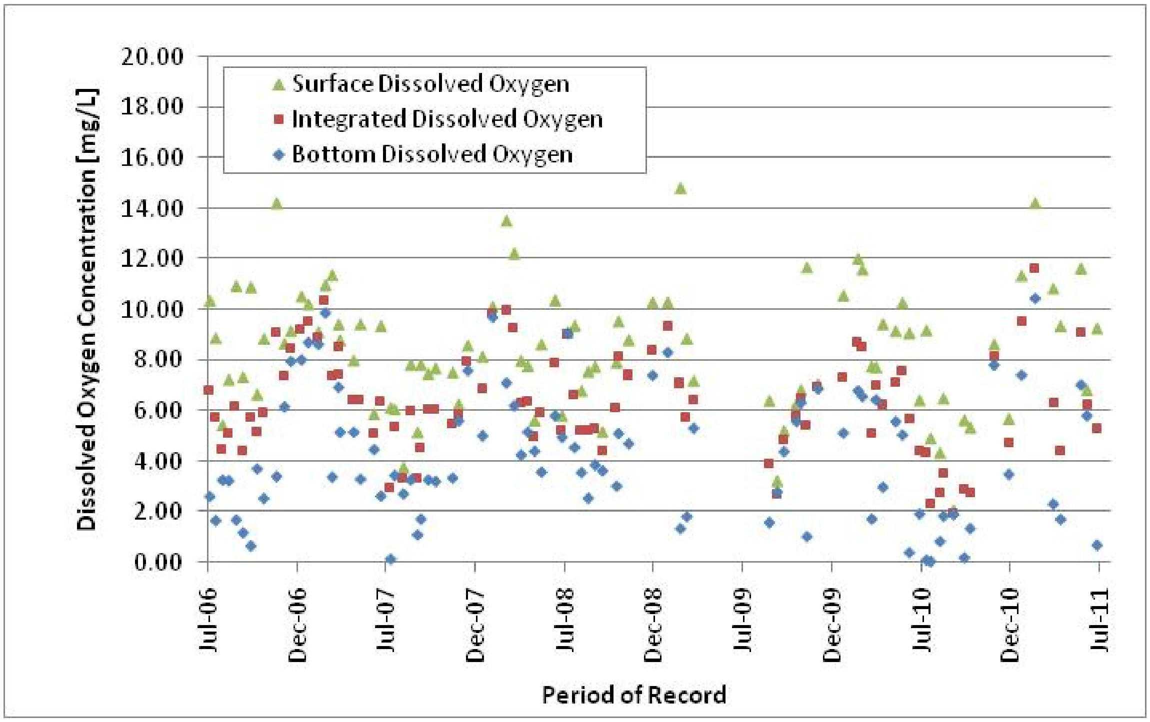


Figure B-8
Lake Elsinore Dissolved Oxygen Concentrations Observed at Station LEE2

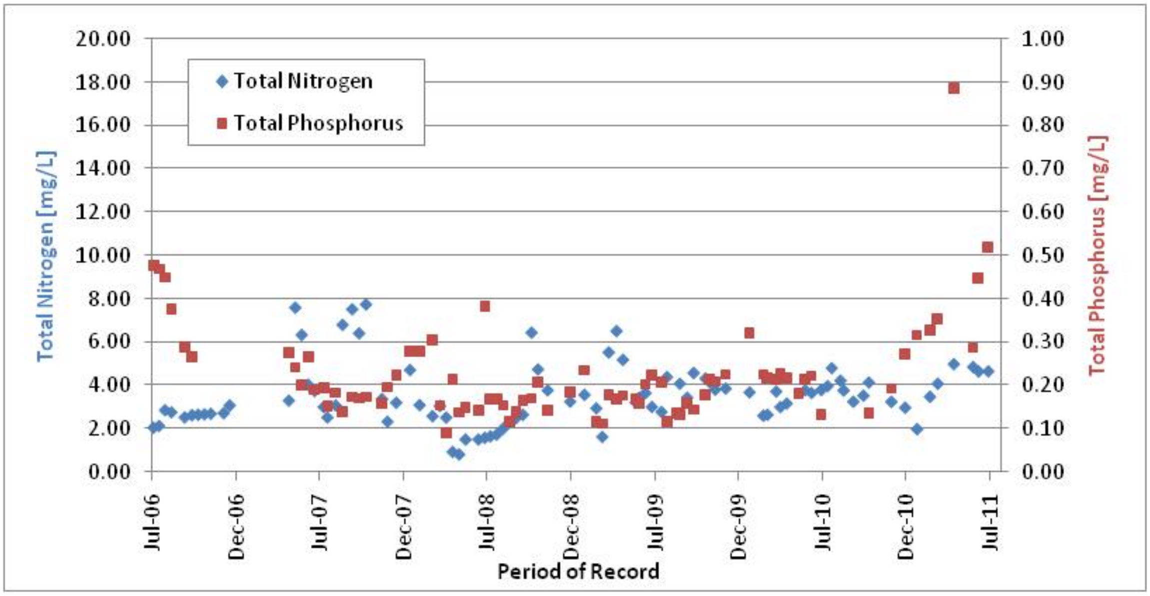


Figure B-9
Lake Elsinore Total Nitrogen and Total Phosphorus Concentrations

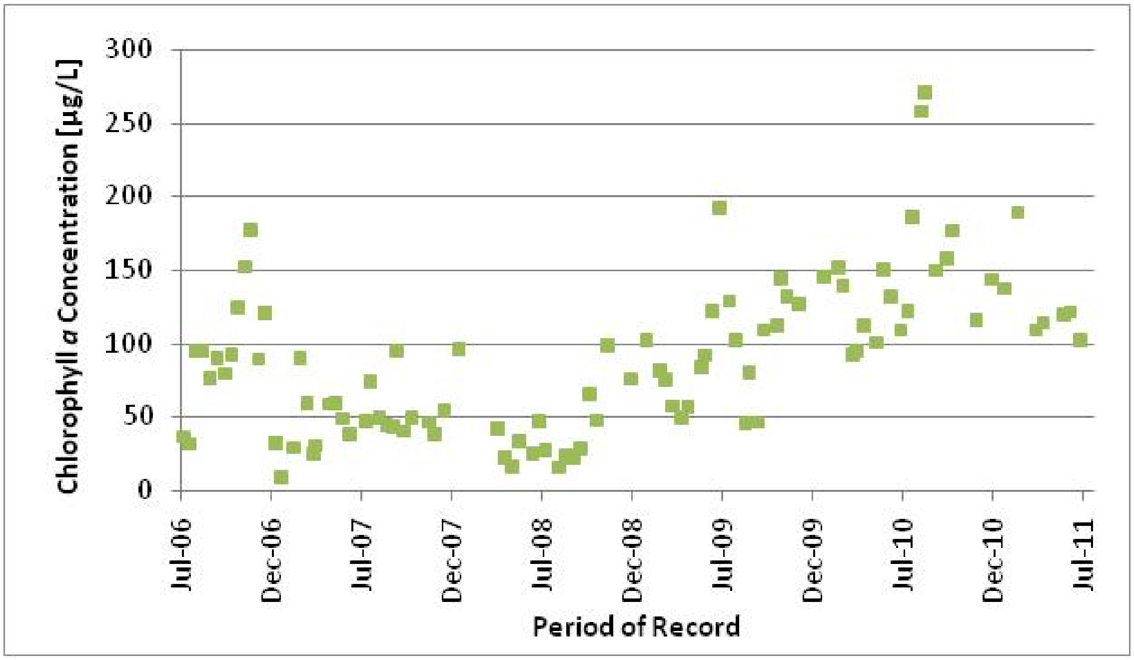


Figure B-10
Lake Elsinore Chlorophyll *a* Concentrations

Table B-10 Lake Elsinore average chlorophyll *a* concentrations consolidated by season

Season	Concentration [µg/L]
Winter	98.9
Spring	74.1
Summer	93.4
Fall	94.1

The Redfield ratio has been used to determine the limiting nutrient for algal growth in the lake. The nutrient that is below the ratio likely limits the growth of phytoplankton (Schindler et al. 2008). For this analysis, a 7:1 ratio for nitrogen to phosphorus (N:P) was used. Figure B-11 shows the N:P ratios observed in Lake Elsinore. For most of the period of record, the observed N:P ratio is greater than 7:1, indicating that phosphorus is the limiting nutrient.

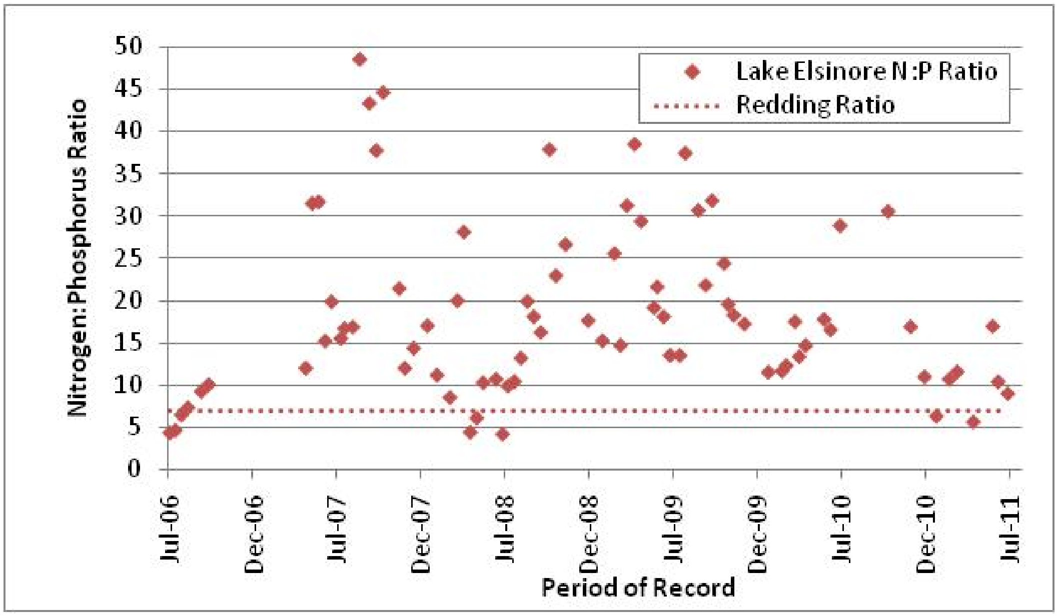


Figure B-11

Observed Lake Elsinore Nitrogen to Phosphorus Ratios

Canyon Lake

EVMWD's NPDES compliance monitoring program for Canyon Lake, which began June 2007, consists of four sampling locations (Figure B-7). Samples from Station CL07 and CL08 are located within the Main Basin and Stations CL09 and CL10 are located in the East Basin.

- Station CL07 – Located at the deepest part of the lake near the dam. The site is generally strongly stratified during the summer.
- Station CL08 – Located mid-lake in the main body of Canyon Lake.
- Station CL09 and CL10 – Two relatively shallow sample locations within the East Basin of the lake that receive local nuisance runoff and discharges from Salt Creek during wet weather events.

Unless stated otherwise, in subsequent tables and figures the Main Basin sampling results are averaged samples from Stations CL07 and CL08, and East Basin sampling results are averaged samples from Stations CL09 and CL10. Samples are collected monthly from October through May, and biweekly from June through September. Table B-11 summarizes Canyon Lake monitoring results for the period July 1, 2007 through June 30, 2011.

Table B-11 Summary - Lake Elsinore Water Quality Data

Parameter	TMDL Compliance Date	Basin Plan Objectives or TMDL Targets	Main Basin 2007- 2011 Results					East Basin 2006 - 2011 Results				
			No. of Sampling Events	Range of Daily Averages	Annual Mean	Annual Median	Standard Deviation	No. of Sampling Events	Range of Daily Averages	Annual Mean	Annual Median	Standard Deviation
Dissolved Oxygen (mg/L) (Station 07 for Main Basin; Stations 09 and 10 for East Basin)	2015	Not less than 5 mg/L above the thermocline	61	0.94 - 13.75	7.01	7.27	2.85	60.00	0.33 - 11.17	6.24	6.01	1.56
	2020	Not less than 5 mg/L daily average in hypolimnion	61	0 - 5.7	0.89	0.21	1.53					
pH (Station 07 for Main Basin; Stations 09 and 10 for East Basin)	---	6-5 - 8.5	68	7.43 - 8.94	8.02	7.98	0.34	68	7.30 - 9.70	8.31	8.22	0.47
Ammonia N (NH4-N) (mg/L) (Station 07 for Main Basin; Stations 09 and 10 for East Basin)	2020	Data Results	70	0.011 - 1.800	0.49	0.44	0.31	70	ND - 1.290	0.40	0.37	0.28
		Acute Criteria Compliance	Exceedances of the acute criterion on: 5/30/08; observed 0.16% of the time (1 out of 644 samples)					Exceedances of the acute criterion on: 5/30/08; observed 0.18% of the time (1 out of 551 samples)				
		Chronic Criteria Compliance	Exceedances of the chronic criterion: 6/18/08, 7/2/08, 7/1/09, 7/24/09, 5/10/10, 6/28/10, 6/12/10, 7/30/10, 8/9/10, 8/30/10, 9/17/10, 10/26/10; Exceedances observed 2.95% of the time (19 out of 644 samples)					Exceedances of the chronic criterion: 5/30/08, 6/6/08, 6/18/08, 7/2/08, 7/24/09, 11/30/09, 6/11/10, 6/28/10; Exceedances observed 4.54% of the time (25 out of 551 samples)				
Total Nitrogen (TN) (mg/L)	2020	Annual average 0.75 mg/L	68	0.33 - 4.37	2.06	2.00	0.93	69	0.35 - 5.49	2.04	1.92	0.92
Total Phosphorus (TP) (mg/L)	2020	Annual average 0.1 mg/L	70	0.33 - 1.74	0.68	0.64	0.25	70	0.09 - 2.27	0.61	0.53	0.36
Chlorophyll *a* (µg/L) (surface samples 0-2 m)	2015	Summer average no greater than 40 µg/L	40	1.5 - 138.3	34.33[1]	29.30	27.49	45	2.5 - 266.1	61.00	38.85	71.62
Chlorophyll *a* (µg/L) (integrated samples)	2020	Summer average no greater than 25 µg/L	60	1.0 - 171.8	37.56[1]	33.49	28.77	60	2.5 - 266.1	56.19	50.92	46.22
Secchi Depth (cm)	---	---	68	18 - 301	119.32	113.25	44.67	69	21 - 231	90.50	86.36	34.26
Total Dissolved Solids (mg/L) (integrated samples)	---	700 mg/L	69	152 - 901	616.63	684.00	215.96	68	336 - 1206	703.82	658.11	223.28

[1] Data presented as annual mean

Figure B-12 shows observed dissolved oxygen concentrations at Station CL07 (closest to the lake spillway). Highly stratified conditions exist throughout most of the year, with the lake bottom concentrations at 0 mg/L for most months. The winter months exhibit greater uniformity in dissolved oxygen concentrations, due to turnover and mixing of the epilimnion and hypolimnion.

Figure B-13 shows observed dissolved oxygen concentrations at Station CL08 (most representative of Main Basin). Dissolved oxygen concentrations are similar to the values found in CL07, with peaks and troughs occurring on the same sample dates as CL07. Highly stratified conditions exist throughout most of the year, with the lake bottom concentrations at 0 mg/L for most months. The winter months exhibit greater uniformity in dissolved oxygen concentrations, due to turnover and mixing of the epilimnion and hypolimnion.

Figure B-14 characterizes observed dissolved oxygen concentrations at Stations CL09 and CL10. Due to the low water depth and inflow from Salt Creek, stratification does not occur in this portion of the lake. Dissolved oxygen concentrations in the East Basin have remained relatively constant throughout the period of record.

Figures B-15 and B-16 show depth integrated total nitrogen and phosphorus observations within the Main Basin and East Basin, respectively. Similar observations occurred at both sample locations. Nitrogen and phosphorus concentrations were generally uniform and did not exhibit seasonal fluctuations or significant changes by depth. Peaks and troughs in nutrient concentrations occurred generally during the same periods. However, the spike in phosphorus concentrations, observed on April 11, 2011 and continuing to the end of the sampling season, was not observed for nitrogen.

Figure B-17 illustrates depth integrated chlorophyll *a* concentrations for the Main Basin and East Basin sample locations. Peaks and troughs of chlorophyll *a* concentrations occurred at the same time at both sites; however, concentrations in the East Basin have been typically higher than the Main Basin. Table B-12 summarizes the average seasonal chlorophyll *a* concentrations at both sample locations. The lowest concentrations have been observed in the spring.

Figure B-18 characterizes the average N:P ratio for both lake basins. For the majority of the period of record, the N:P ratio of N:P is less than 7:1, indicating that nitrogen is the limiting nutrient.

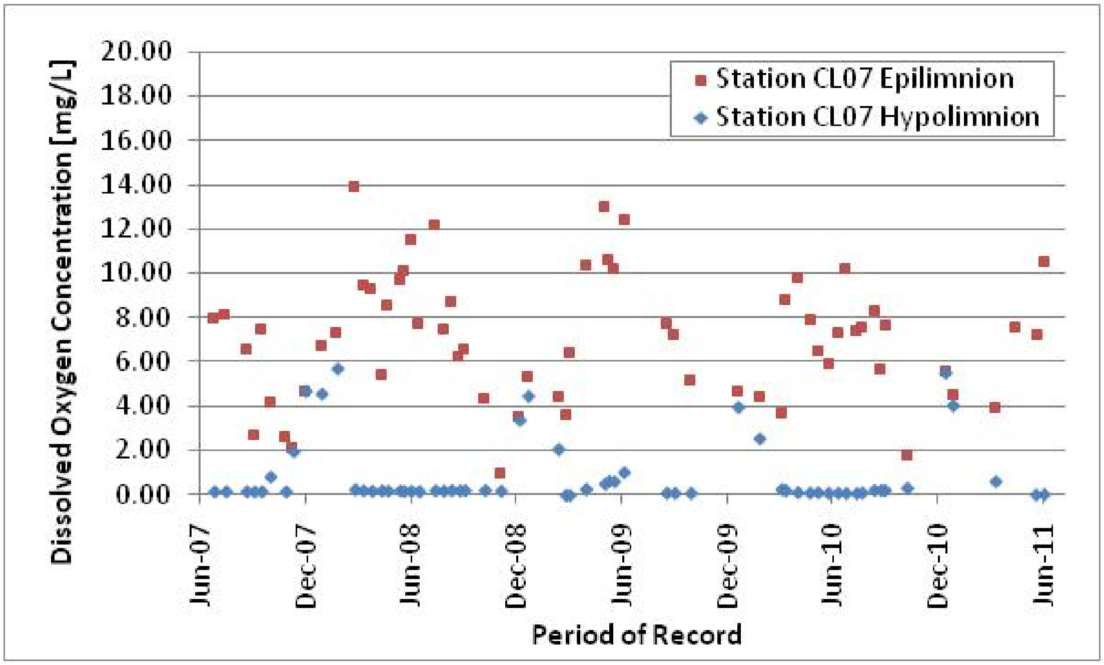


Figure B-12
Canyon Lake Dissolved Oxygen Concentrations at Station CL07

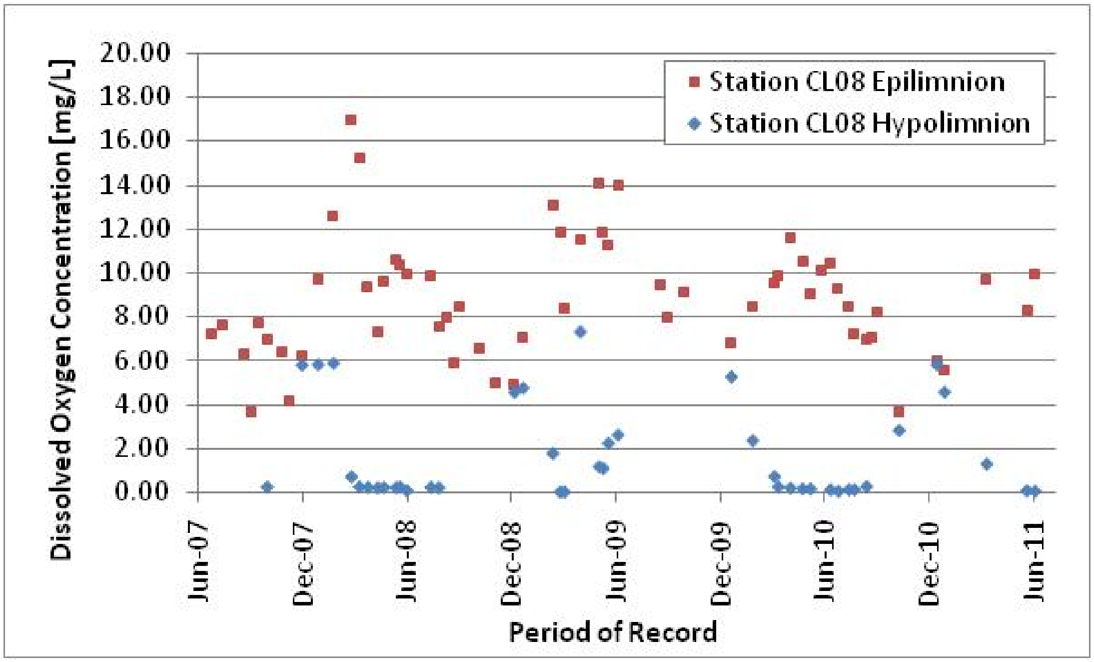


Figure B-13
Canyon Lake Dissolved Oxygen Concentrations at Station CL08

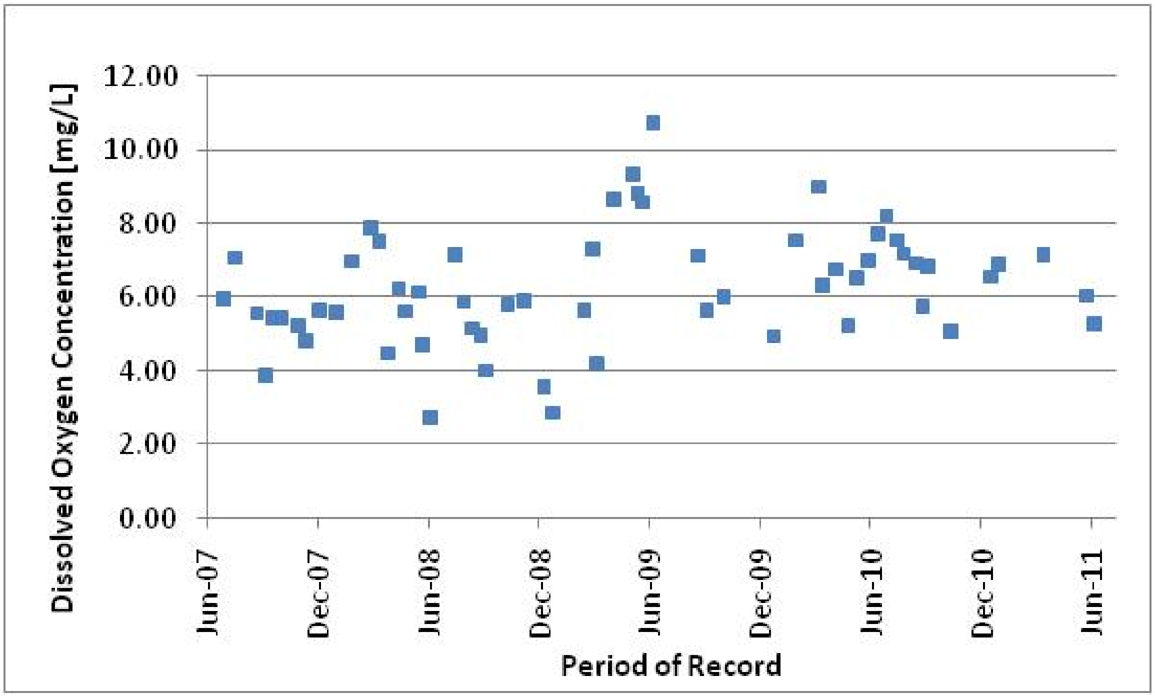


Figure B-14

Canyon Lake Dissolved Oxygen Concentrations at East Basin Sample Locations (CL09 and CL10)

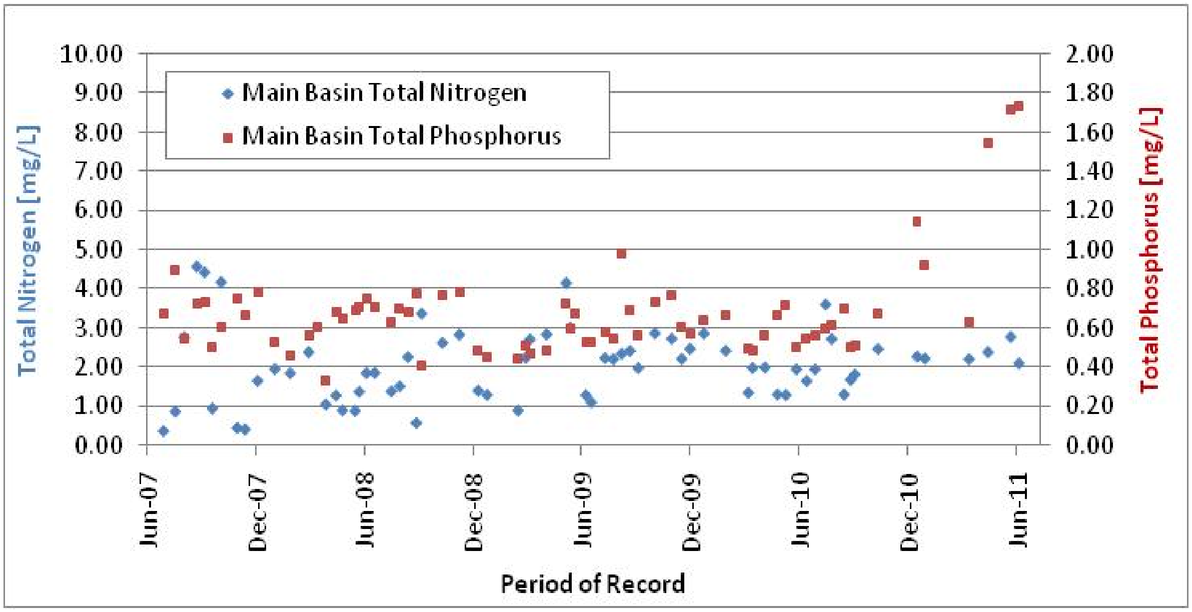


Figure B-15

Canyon Lake Total Nitrogen and Total Phosphorus Concentrations in the Main Basin

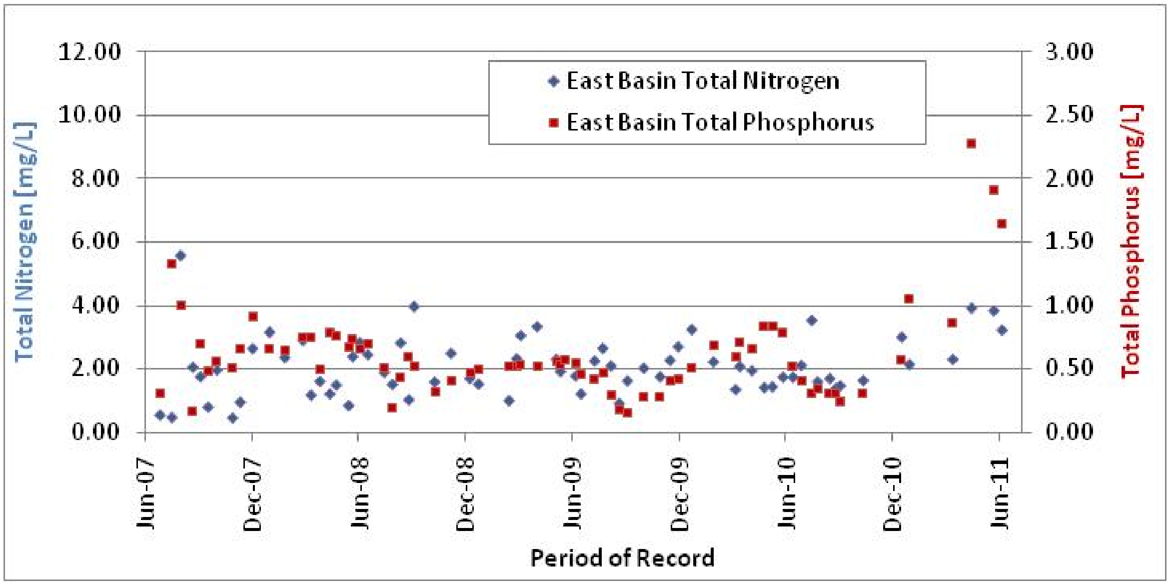


Figure B-16

Canyon Lake Total Nitrogen and Total Phosphorus Concentrations in the East Basin

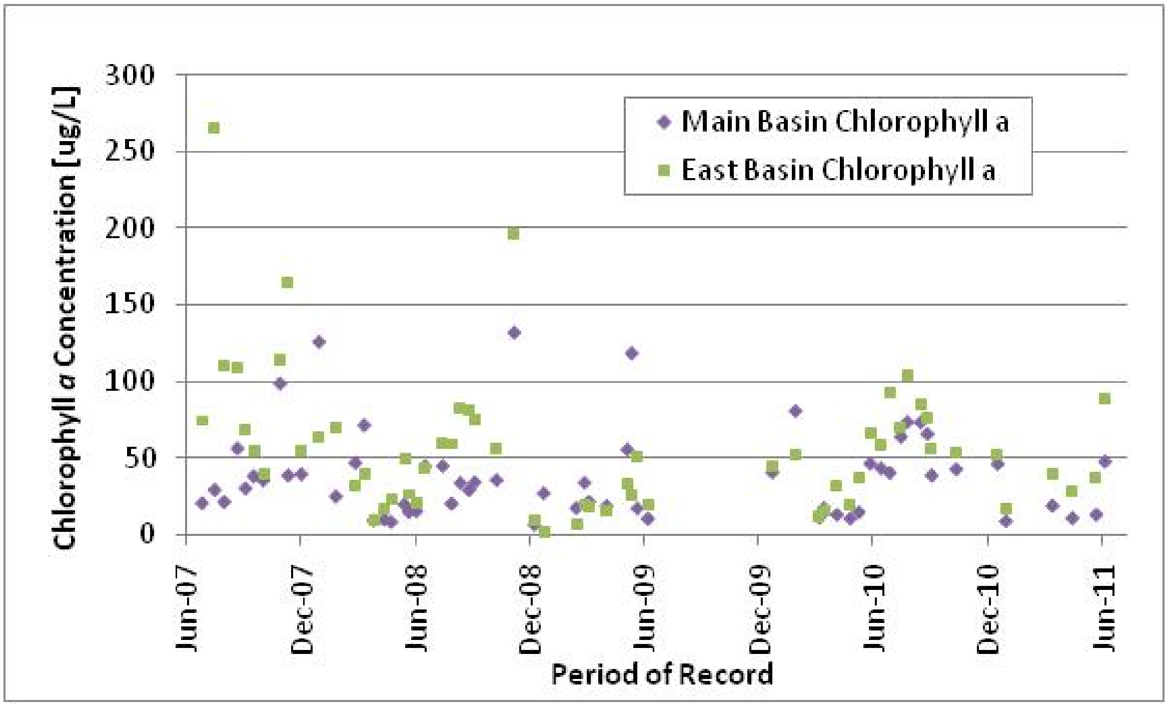


Figure B-17

Canyon Lake Chlorophyll *a* Concentrations

Table B-12 Canyon Lake average Chlorophyll *a* Concentrations (µg/L) by Season

Season	Main Basin	East Basin
Winter	41.4	36.7
Spring	27.9	25.4
Summer	35.1	74.0
Fall	51.6	87.8

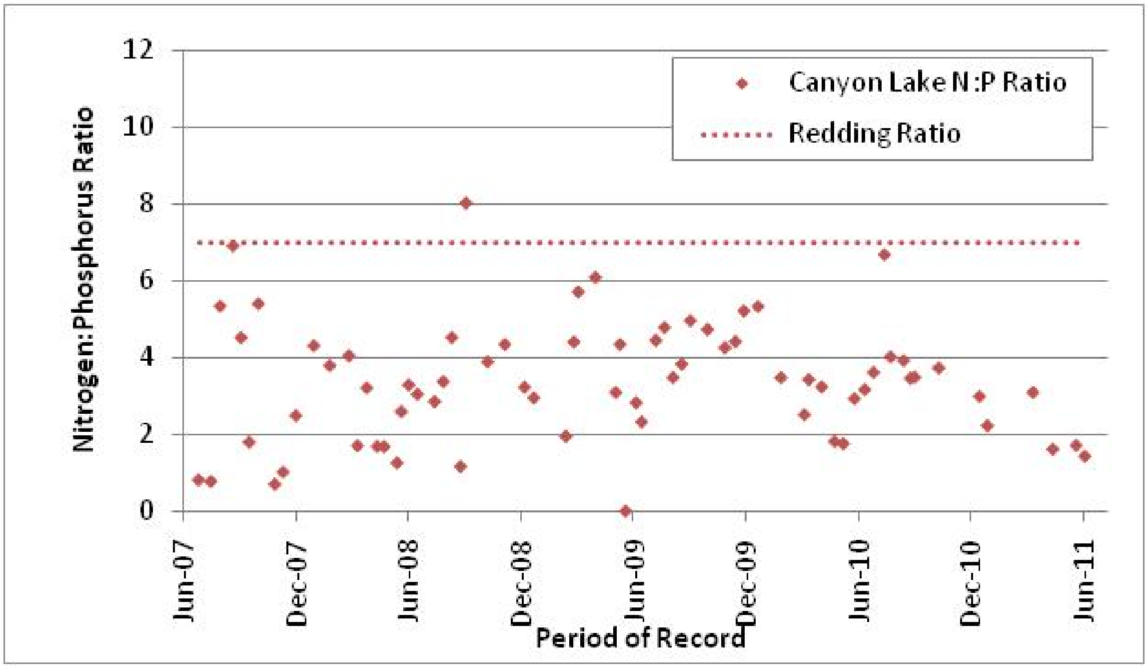


Figure B-18
Observed Canyon Lake Nitrogen to Phosphorus Ratios

San Jacinto Watershed

As part of the Phase I San Jacinto River Watershed Monitoring Program, water quality samples were collected from four sample locations during wet weather events (Figure B-19):

- Salt Creek at Murrieta Rd – Area tributary to this sample location includes the southern portion of the San Jacinto watershed, with land uses consisting of irrigated croplands and residential.
- Goetz Road – Tributary area includes the northern half of the San Jacinto watershed; land use includes urban, irrigated croplands, residential, and open space. This monitoring location has the largest tributary area, but much of the water is captured by nearby Mystic Lake.

- Canyon Lake Spillway – Only during high storm events is water released from Canyon Lake to Lake Elsinore. Samples are gathered from this site only when water is released.

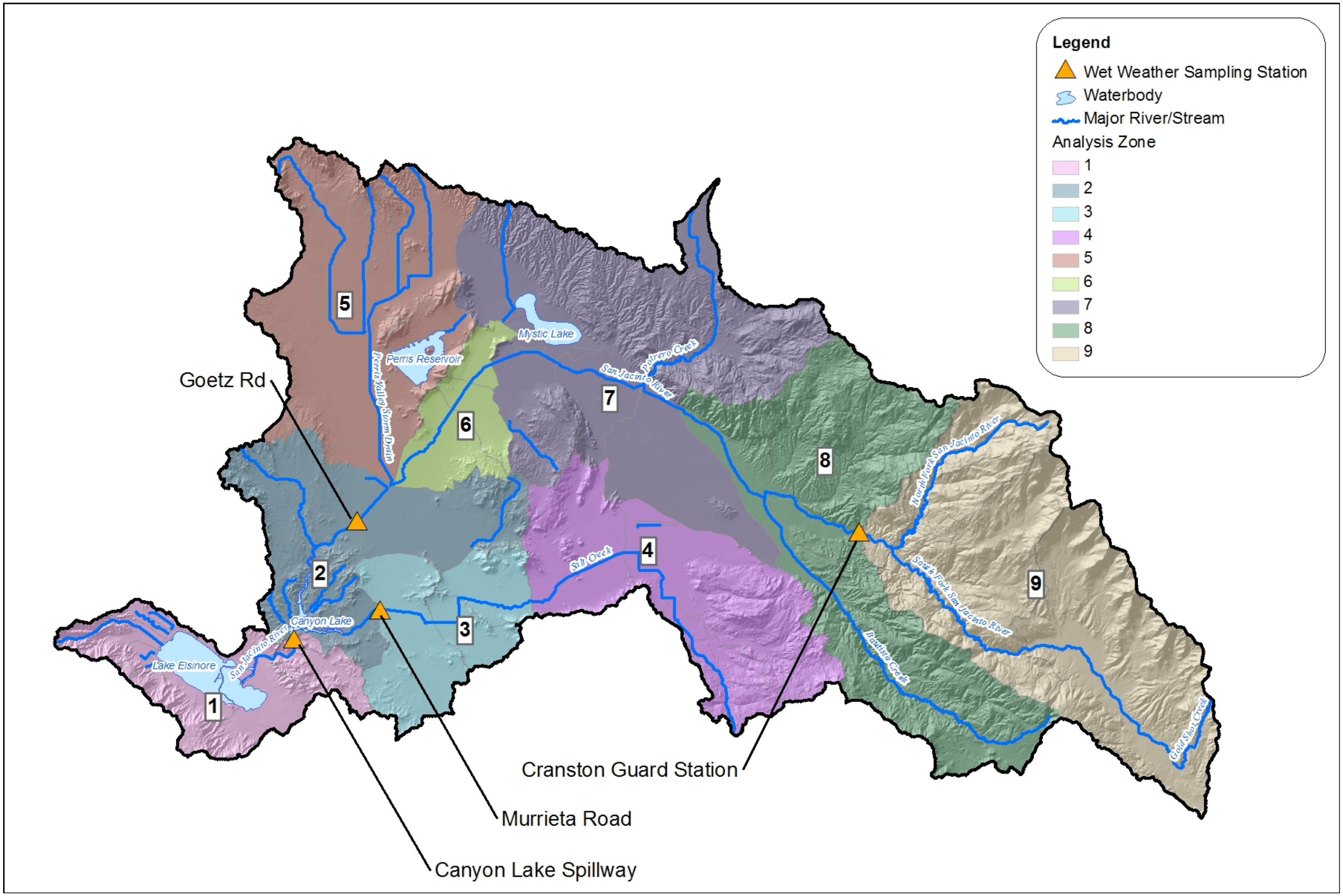
- Cranston Guard Station – This station is located at the eastern portion of the watershed. This station experiences the highest annual flows compared to the other stations. Sampling at this station is conducted by the United States Forest Service, and is dependent on whether adequate funding is allocated through Congress. Land use upstream of this site is forested area.

- A fifth station, San Jacinto River at Ramona Expressway, would be sampled if Mystic Lake overflows; however, since the implementation of this monitoring program no such overflows have occurred.

Samples are collected throughout observed storms at different points of the hydrograph to obtain a range of concentrations across the storm event. Sampling methodology is described in detail in the Lake Elsinore & Canyon Lake Nutrient TMDL Annual Water Quality Monitoring Reports. Figures B-20 and B-21 illustrate the observed water quality concentrations for total phosphorus and total nitrogen, respectively; Table B-13 summarizes the water quality data. Sample results indicate that nutrient concentrations tend to be higher during the beginning of the storm (first flush) and then decrease during later portions of the storm event. San Jacinto River at Goetz Road and Salt Creek at Murrieta Road have the highest concentrations of total nitrogen based on observed median concentrations, while the Goetz Road site has the highest total phosphorus. The average N:P ratio was calculated for each watershed water quality sample site; all ratios were less than 7.1, indicating that nitrogen is the limiting nutrient in wet weather runoff.

Table B-13. Summary of Nutrient Water Quality Data for San Jacinto Watershed (mg/L)

Waterbody	Nutrient	N	Average Concentration	Median Concentration	Standard Deviation	Average N:P Ratio
Salt Creek at Murrieta Road	Total Phosphorus	108	0.75	0.66	0.47	4.2
	Total Nitrogen	108	2.47	2.32	0.91	
San Jacinto River at Goetz Road	Total Phosphorus	90	1.44	0.95	1.84	2.7
	Total Nitrogen	90	2.73	2.26	1.70	
Canyon Lake Spillway	Total Phosphorus	59	0.57	0.50	0.21	3.2
	Total Nitrogen	59	1.78	1.76	0.55	
Cranston Guard Station	Total Phosphorus	29	0.65	0.49	0.44	2.4
	Total Nitrogen	29	1.22	1.10	0.57	



Comprehensive Nutrient Reduction Plan For MS4 Permittees in Canyon Lake and Lake Elsinore Watershed	Dec. 1, 2011	0 2 4 8 Miles	N W E S	**Figure B-19**	CDM
	Watershed Water Quality Monitoring Sites and Watershed Analysis Zones				

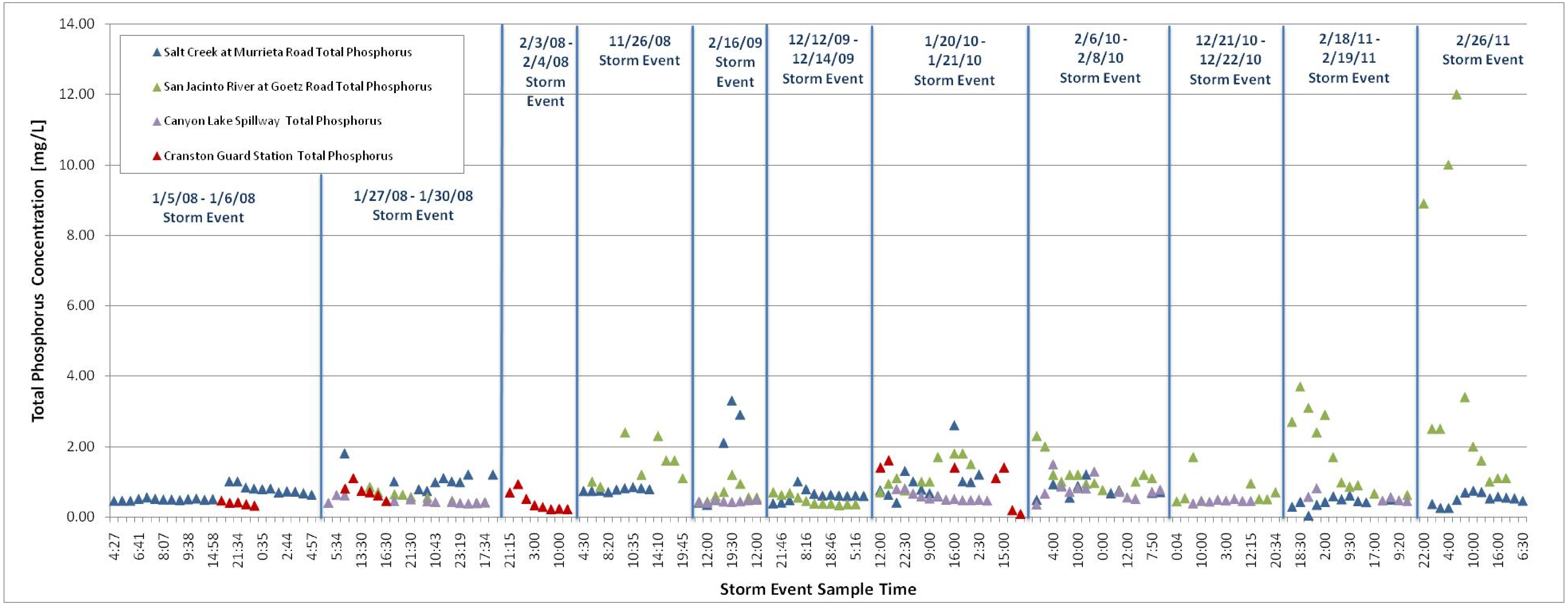


Figure B-20
Wet-Weather Sampling Total Phosphorus Concentrations

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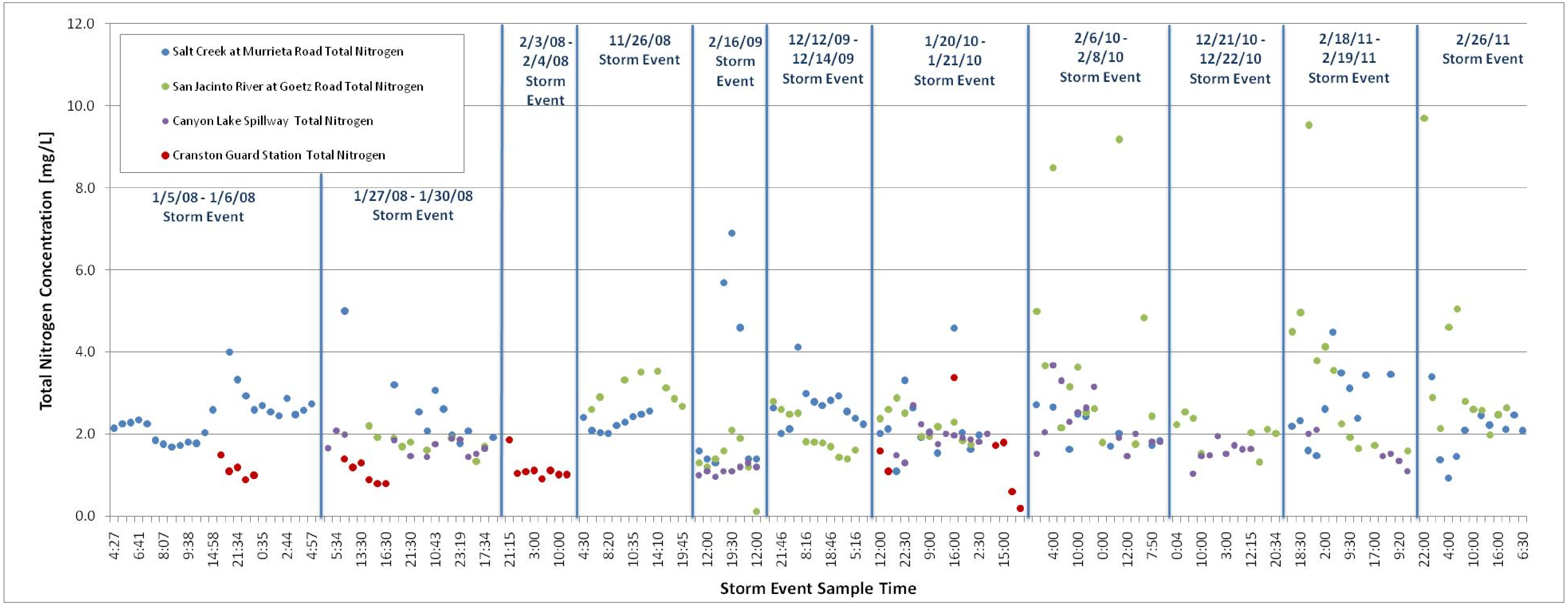

Figure B-21
Wet-Weather Sampling Total Nitrogen Concentrations

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MS4 System Monitoring

Wet weather monitoring during February 2011 was conducted by RCFCD&WCD at six outfalls to receiving waterbodies in the San Jacinto River watershed. The data collected at the Meadowbrook site consistently have significantly higher nutrient concentrations than would be expected from urban stormwater and would be candidates for follow up investigation (Table B-14). Other monitored outfalls have average nutrient concentrations that are generally lower than concentrations in CORE receiving waterbody monitoring sites for the two primary inputs to Canyon Lake from the San Jacinto River and Salt Creek.

Table B-14. Summary of Nutrient Water Quality Data for Phase 2 TMDL MS4 Outfall Monitoring during February 2011

Waterbody	Nutrient	N	Average Concentration	Coefficient of Variation
Hemet Channel at Sanderson Avenue	Total Phosphorus	9	0.28	0.28
	Total Nitrogen	9	1.19	0.25
San Jacinto River Upstream of Lake Elsinore	Total Phosphorus	7	0.59	0.26
	Total Nitrogen	7	1.59	0.22
Kitching St. Channel at Iris Avenue	Total Phosphorus	9	0.43	0.26
	Total Nitrogen	9	2.05	0.32
Meadowbrook at Highway 74	Total Phosphorus	10	1.21	0.41
	Total Nitrogen	10	11.83	0.21
Perris Valley Storm Drain at Nuevo Road	Total Phosphorus	11	0.82	0.32
	Total Nitrogen	11	2.71	0.49
Sierra Park Drain in Canyon Lake	Total Phosphorus	10	0.33	0.33
	Total Nitrogen	10	2.55	0.22

In addition to summary statistics, correlations were evaluated between nutrients and suspended sediment for samples collected during February 2011. TP showed a greater correlation strength with sediment than TN. The results showed statistically significant correlations, as follows:

- TN and TP: Pearson's r 0.78, $df = 54$, $p < 0.001$
- TN and TSS: Pearson's r 0.37, $df = 54$, $p = 0.004$
- TP and TSS: Pearson's r 0.76, $df = 54$, $p < 0.001$

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Attachment C
Table of Contents

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C-1 Executive Summary

In order to achieve compliance with the Lake Elsinore and Canyon Lake nutrient TMDLs, the responsible parties, which include the MS4 Permittees discharging urban runoff, considered: (1) implementing watershed-based activities and projects that reduce the discharge of nutrients into the lake; (2) implementing projects in the lakes that reduce in-lake loads and concentrations projects; or (3) some combination of watershed and in-lake BMPs. The December 31, 2011 draft of the CNRP contained an evaluation of different strategies for in-lake reduction of nutrient levels in Canyon Lake, and determined that HOS would be the most effective means of complying with the nutrient TMDL. The basis for this determination were studies showing that suppression of nutrient flux from lake bottom sediments by creating an oxic condition at the sediment water interface would more than offset the load reduction needed to reduce existing urban and septic loads to the allowable WLA/LAs, after accounting for estimated watershed loads reduction.

In January of 2012, the Task Force sought Michael Anderson to conduct additional studies to evaluate chemical addition alternatives and to determine the potential impact of HOS on in-lake TMDL response targets for chlorophyll-a and DO. The studies were intended to provide additional confirmation on the selection of a HOS by assessing whether it can be a whole-lake solution, or to revise the proposed in-lake nutrient management strategy to use chemical addition or regulatory approaches to achieve the response targets. Section C.2 of this attachment provides the results of these studies. The key findings from each study that led to a revision to the Canyon Lake in-lake nutrient management strategy are summarized below:

- Task 1: Estimate Rate at Which Phosphorus is Rendered No Longer Bioavailable in Sediments. This task showed that settled nutrients in lake-bottom sediments continue to release nutrients to the water column for several decades. Thus a reduction in external loads from CNRP implementation may not result in a significant change to internal nutrient cycling prior to 2020.

- Task 2. Evaluation of Long-Term Reduction of Phosphorus Loads from Internal Recycling as a Result of Hypolimnetic Oxygenation in Canyon Lake: This study showed that HOS will not provide sufficient nutrient reduction in years with above average rainfall to achieve response target for chlorophyll-a. In its March 31, 2012 comment letter, the Regional Board states that if the WLAs and LAs are effectively offset with in-lake BMPs, but response targets are still not achieved, then the TMDL would be reopened to reduce WLAs and LAs. Thus, HOS alone is not sufficient to achieve compliance with the TMDL.

- Task 3. Evaluation of Alum Phoslock, and Modified Zeolite to Sequester Nutrients in Inflow and Improve Water Quality in Canyon Lake. This study evaluated the potential water quality benefit that could be achieved with chemical additional alternatives. The DYRESM-CAEDYM results showed that a reduction in dissolved orthophosphate at the lake inflows from ~0.35 mg/L to 0.20 mg/L would shift the lake to P-limitation and reduce average annual chlorophyll-a to below the final numeric target of 25 ug/L. The study also evaluated potential doses and associated costs for alum, Phoslock, or zeolite.

- Task 4. Predevelopment Condition Assessments for Canyon Lake (Task 4a) and Lake Elsinore (Task 4b). To estimate the controllability of water quality in Canyon Lake and Lake Elsinore, the DYRESM-CAEDYM model was run for a scenario with external loads reflective of a completely undeveloped watershed. This scenario showed chlorophyll-a consistently below the water quality objectives. For DO, exceedences of the water quality objectives were estimated to occur as much as 50 percent of the time in Canyon Lake. Thus, a completely undeveloped watershed would not comply with the DO numeric target, as stated in the TMDL. The MS4 Permittees plan to modify the TMDL numeric target at the next reopener of the TMDL, to allow for exceedences of the DO water quality objective within the hypolimnion as would be expected if the watershed were completely undeveloped.

- Task 5a. Simulations Using Refined Model Parameter Set Under Steady State Conditions for Lake Elsinore. This analysis updated previous evaluations of management alternatives. The analysis quantifies the improvement to lake TP and chlorophyll-a that may be achieved with reclaimed water addition, carp fishery management, and aeration. Results suggest that, at a minimum, all three management strategies will be needed to comply with the TMDL

- Task 5b. Evaluate Effects of Management Alternatives for Canyon Lake on External Nutrient Loading to Lake Elsinore. This study updated the DYRESM-CAEDYM model to create a linkage between Canyon Lake and Lake Elsinore, for testing whether improved lake water quality in Canyon Lake would reduce pass-through loads to Lake Elsinore. Results showed limited pass-through load reductions as a result of in-lake BMPs in Canyon Lake.

- Task 6. Predicted Water Quality in Canyon Lake with In-Lake Alum Treatments and Watershed BMPs. This task involved simulation of the water quality response to proposed watershed BMPs and in-lake alum additions included in the CNRP. Results showed that the final numeric target for chlorophyll-a is expected to be achieved with the proposed project (Scenario 12 in the TM). For DO, the results show that the interim (epilimnion) DO target is expected to be achieved and significant progress toward the final (hypolimnion) target. These results are the primary basis for the Canyon Lake compliance demonstration presented in Section 3 of the CNRP

When alum is added to a waterbody, an aluminum hydroxide precipitate known as floc is formed. The floc binds with phosphorus in the water column to form an aluminum phosphate compound which will settle to the bottom of the lake or reservoir. EVMWD conducted jar tests to determine the reduction of TP that could be achieved at varying doses of alum. Samples collected at all four TMDL monitoring stations were collected and varying amounts of alum were added to each. Jar test results are summarized in Section C.3 of this Attachment

Technical Memorandum

Task 4b: Evaluate Water Quality in Lake Elsinore Under Pre-Development Conditions

Objective

The objective of this task was to evaluate water quality conditions in Lake Elsinore assuming no development in the watershed.

Approach

A DYRESM-CAEDYM model for Lake Elsinore was developed to predict water quality in Lake Elsinore assuming no development in the watershed. As in previous simulations, the 2002-2011 time period was evaluated, with the same meteorological conditions as used in the Canyon Lake simulations, with overflow from Canyon Lake and runoff from the local watershed serving as the primary water and external nutrient inputs to the lake. Direct precipitation on the lake surface was included in the water budget calculations, while atmospheric deposition also provided a limited amount of direct nutrient additions (somewhat arbitrarily set at 10% of current levels). Local runoff volumes were estimated based upon precipitation rates and the area of the local watershed (54 km^2) assuming a runoff coefficient of 0.3 (Anderson, 2006). Area-volume-depth relationships were taken from the analytical model previously developed as well (Anderson, 2006). Nutrient concentrations in the local runoff were estimated from pre-development watershed values from TetraTech, while outflow nutrient concentrations were taken from predicted values of the pre-development simulation for Canyon Lake (Anderson, 2012c).

Note that aspects of this pre-development scenario are quite different than the true pre-development condition at the lake, since (i) we are using the deeper, smaller reconfigured lake basin developed as part of the Lake Elsinore Management Plan, and (ii) Canyon Lake is retained as an upstream impoundment on the San Jacinto River despite its relatively new role in the watershed. For these and several other reasons, the results presented herein should be viewed as a semi-quantitative estimate of a hypothetical pre-development condition here, and could thus be expected to differ from conditions that might be inferred from paleolimnological investigations.

Results

Lake Elsinore, prior to development in the watershed, was predicted to be relatively well-mixed vertically throughout most years (Fig. 1a). This is a result of the low nutrient levels and low corresponding chlorophyll a concentrations (described below) that yield high predicted water clarity. Based upon the predicted chlorophyll a concentrations, the Secchi depth of the lake is estimated to be 2-4 m or more much of the time, which allows for penetration of shortwave radiation to considerable depths in the lake. Combined with the long fetch and strong afternoon winds, the lake is predicted to be mixed to the bottom at lower lake elevations and during intervals of particularly clear water (Fig. 1a). This differs markedly from existing conditions in the lake, where low transparency limits heat penetration, restricts vertical mixing and maintains a relatively thin epilimnion when present.

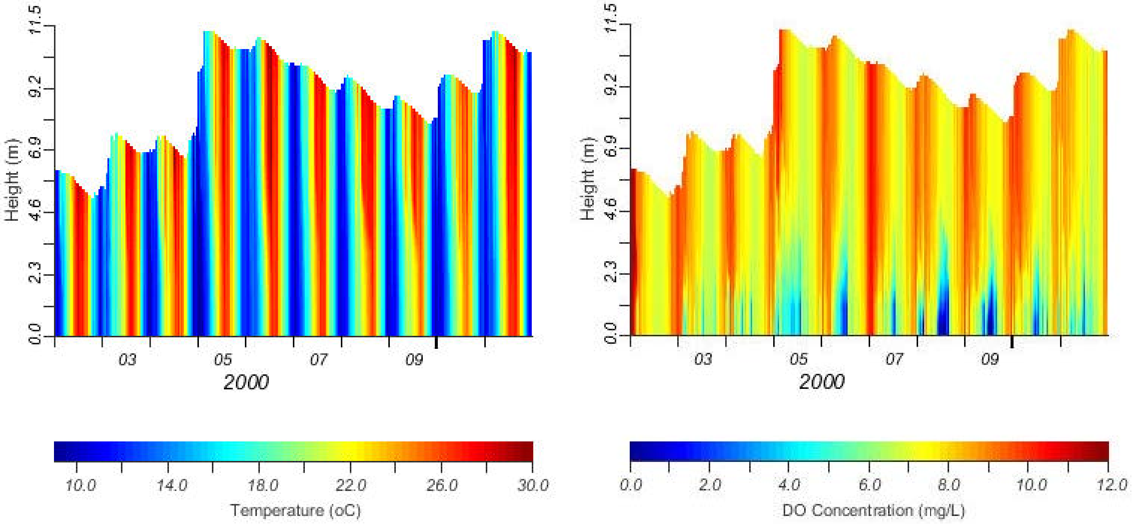

Fig. 1. Simulation results for Lake Elsinore under the pre-development scenario (using meteorological conditions for the 2002-2011 period): a) temperature and b) dissolved oxygen concentration.

The improved mixing in the lake was also predicted to maintain higher concentrations of dissolved oxygen (DO) in the water column, including concentrations near the bottom sediments much of the time (Fig. 1b). While markedly improved relative to existing conditions, where up to 75% of the bottom sediments are often anoxic (<1 mg/L) for most of the summer (Lawson and Anderson, 2007), some intervals of reduced DO concentrations were predicted near the sediments at higher lake levels *e.g.*, in the summers of 2006-2009. Nonetheless, anoxia at 1 m above the deepest point on the lake was found only 1.7% of the days in this 10 yr simulation period.

As alluded to above, predicted concentrations of nutrients were generally quite low relative to existing conditions, with concentrations generally 0.02 - 0.06 mg/L, although higher concentrations were found above the bottom sediments in the summer of 2008 and 2009 (Fig. 2a) when DO levels were low (Fig. 1b). Predicted total N concentrations within the water column were below existing concentrations as well, ranging from 0.40 to 1.2 mg/L (Fig. 2b). As with total P, some increase in total N was observed near the sediments in the summer of 2008 and 2009. The predicted TN:TP ratios typically near 20 suggest that the lake will likely be weakly P-limited under pre-development conditions.

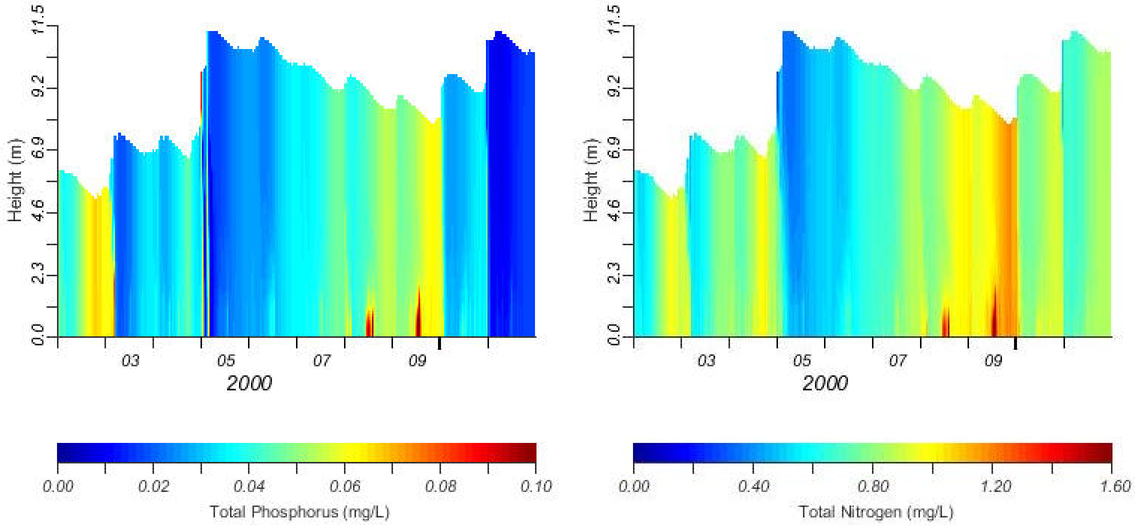

Fig. 2. Simulation results for Lake Elsinore under the pre-development scenario (using meteorological conditions for the 2002-2011 period): a) total P and b) total N concentration.

The low nutrient concentrations were predicted to support chlorophyll a levels generally 12-25 μg/L (Fig. 3a), values that stand in sharp contrast to some of the concentrations seen, e.g., in the summer of 2002 and 2004 that exceeded 300 μg/L (Veiga-Nascimento and Anderson, 2004). Simulations suggest that blue-green algae (cyanobacteria) will comprise the dominant algal species in the lake even with reduced nutrient levels, although diatoms and green algae were predicted to be present as well (Fig. 3b).

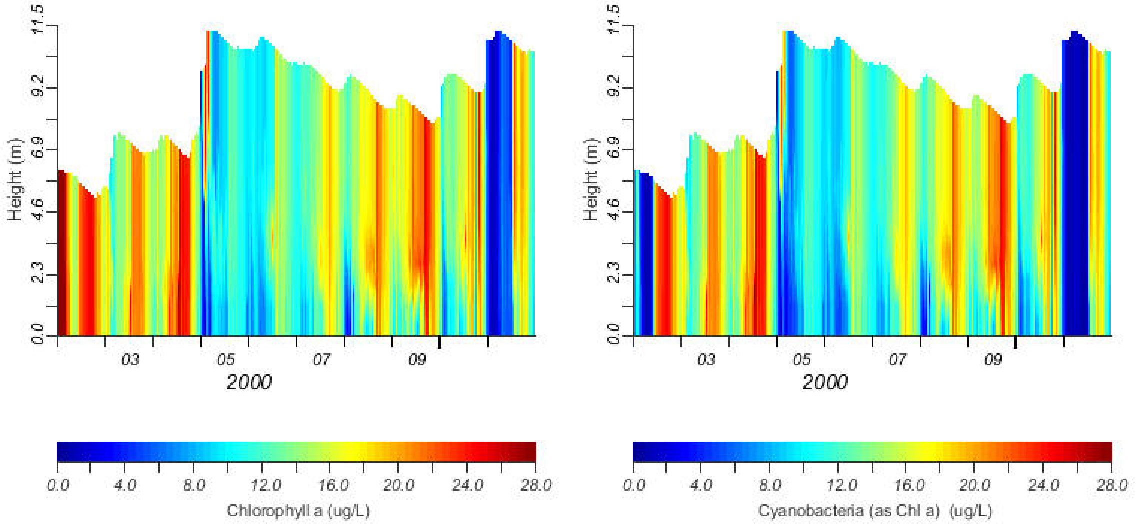

Fig. 3. Simulation results for Lake Elsinore under the pre-development scenario (using meteorological conditions for the 2002-2011 period): a) chlorophyll a and b) cyanobacteria.

Dissolved nutrient concentrations in the water column were generally predicted to be low, although some dissolved PO_4-P was predicted in the fall of 2003 and in 2008-2009 (Fig. 4a). Dissolved PO_4-P comprised essentially all of the phosphorus just above the deepest bottom sediments in the summer of 2008 and 2009, reflecting internal loading during periods of stratification (Fig. 1a) and low DO conditions (Fig 1b). Ammonium-N concentrations were uniformly low in the upper water column, with limited accumulation near sediments during intervals of stratification and anoxia (Fig. 4b). Little NO_3-N was also predicted, consistent with phytoplankton and bacteria utilizing the available inorganic forms (not shown).

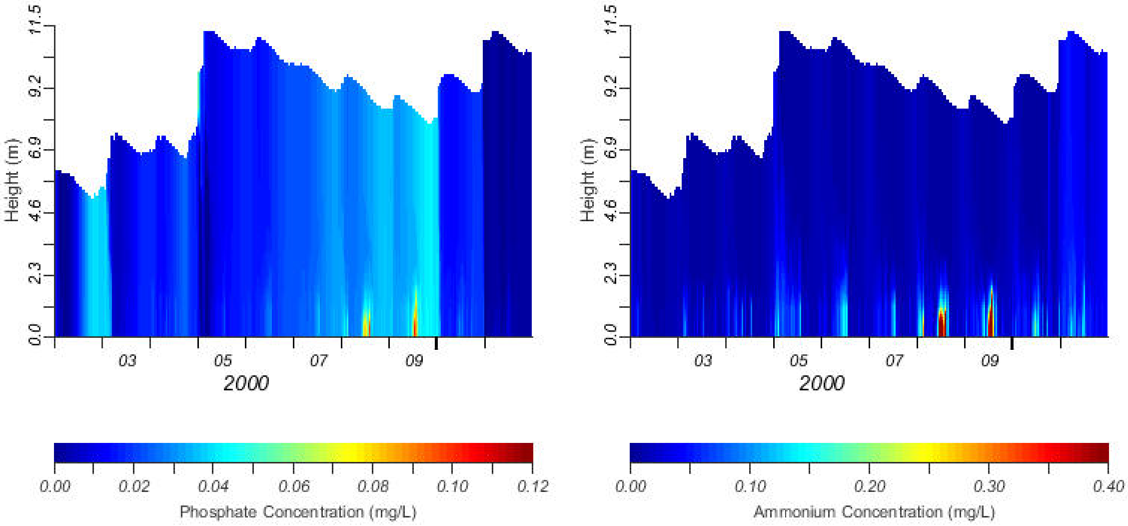

Fig. 4. Simulation results for Lake Elsinore under the pre-development scenario (using meteorological conditions for the 2002-2011 period): a) PO_4-P and b) NH_4-N concentrations.

For comparison with the nutrient TMDL numeric targets for Lake Elsinore, data from the simulations used to calculate annual average total P, total N and summer average chlorophyll a concentrations, as well as the number of days each year when DO concentrations above bottom sediments were <5 mg/L (Table 1). As expected from Fig. 2a, annual average total P levels were low (mean value of 0.036 mg/L), although they did exhibit some interannual variation (0.024 - 0.056 mg/L) related to hydraulic and external nutrient loading, lake surface elevation and related factors (Table 1). Notwithstanding, these simulations suggest that the water quality in the lake prior to development in the watershed would come in well-below the TMDL numeric target for total P of 0.1 mg/L.

In contrast, the model predicted annual average concentrations of total N in Lake Elsinore that would be near or frequently exceed the numeric target of 0.75 mg/L (Table 1). For this 10-year period of time, the predicted annual total N ranged from a low of 0.44 mg/L in 2005 to a high of 1.06 mg/Lin 2009, and averaged 0.76 mg/L, just exceeding by the narrowest of margins the numeric target.

Predicted chlorophyll a concentrations were less variable than found under existing conditions, and annual summer-averaged values ranged only from 9.6 - 21.7 μg/L. Over the 10-year simulation period, the summer chlorophyll a concentration was predicted to averaged 15.7 μg/L, a value significantly below the TMDL numeric target of 25 μg/L (Table 1).

Table 1. Predicted mean annual concentrations of total P, total N, and summer chlorophyll a, and number of days each year DO <5 mg/L 1m above bottom sediments.

Year	Total P (mg/L)	Total N (mg/L)	Chlorophyll a (μg/L)	# days DO < 5 mg/L
Target	*0.10*	*0.75*	*25*	*≥5*
2002	0.052	0.74	20.6	0
2003	0.033	0.70	17.5	13
2004	0.035	0.84	21.7	2
2005	0.024	0.44	9.6	111
2006	0.029	0.56	12.2	78
2007	0.040	0.75	14.9	43
2008	0.048	0.89	16.2	121
2009	0.056	1.06	18.8	99
2010	0.032	0.83	15.5	68
2011	0.013	0.76	10.4	58
Average	*0.036*	*0.76*	*15.7*	*59*

The concentration of DO 1 m above the bottom sediments at the deepest part of the lake was strongly dependent upon lake level and duration and strength of thermal stratification (Fig. 1a). The shallow depth and well-mixed conditions in 2002 resulted in concentrations above 5 mg/L throughout the year, while higher lake levels in 2005 and beyond, combined with evapoconcentration of nutrients and other factors, increased the frequency and duration of bottom water DO concentrations below the 5 mg/L target (Table 1). As noted previously, however, anoxic conditions when the DO concentrations declined below 1 mg/L, a threshold where significant biogeochemical transformations such as Fe reduction and hydrogen sulfide production often commence, were predicted to be rare, occurring only 1.7 % of the days from 2002-2011.

Conclusions

Results from these simulations suggest that:

(i) Conditions in Lake Elsinore prior to development in the watershed would be mesotrophic to weakly eutrophic, as opposed to the eutrophic-hypereutrophic conditions presently.

(ii) Greater water clarity would allow heat to penetrate to greater depths, resulting in better mixing and improved DO conditions throughout much of the water column, especially at low to moderate lake levels.

(iii) Development of some thermal stratification and reductions in DO were predicted especially at higher lake levels, although intense and prolonged anoxia, fish kills and so on, are not generally expected.

(iv) Annual average concentrations of total P and summer average concentrations of chlorophyll a were predicted to below their respective TMDL numeric targets.

(v) The average total N concentration for the 10-year simulation period was at the numeric target of 0.75 mg/L, while DO concentrations were predicted to drop below the target of 5 mg/L above the bottom sediments an average of 59 days in a given year.

References

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Anderson, M.A. 2012b. *Evaluation of Alum, Phoslock and Modified Zeolite to Sequester Nutrients in Inflow and Improve Water Quality in Canyon Lake.* Draft Technical Memorandum, Task 3, to LESJWA. 12 pp.

Anderson, M.A. 2012c. *Evaluate Water Quality in Canyon Lake Under Pre-Development Conditions and TMDL-Prescribed External Load Reductions.* Draft Technical Memorandum, Task 4a, to LESJWA. 8pp.

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Technical Memorandum

Task 5b: Evaluate Effects of Management Alternatives for Canyon Lake on External Nutrient Loading to Lake Elsinore

Objective

The objective of this sub-task was to evaluate the effects of various previously considered management alternatives for Canyon Lake (e.g., HOS, watershed BMPs, microfloc alum injection) on the external loading of nutrients downstream to Lake Elsinore.

Approach

The nutrient loading to Lake Elsinore from Canyon Lake for the 2002-11 simulation period was evaluated for the different management options considered for Canyon Lake. Four specific scenarios were evaluated: (i) reference conditions (existing conditions for 2002-2011), (ii) implementation of TMDL-prescribed reductions in nutrient loading from the watershed, (iii) operation of the hypolimnetic oxygenation system (HOS), and (iv) treatment of inflow with alum to a PO_4-P concentration of 0.20 mg/L.

Results

Annual flows from Canyon Lake to Lake Elsinore varied over the past decade, with very high flows in 2005 and no or negligible flows in 2002, 2006 and 2007 (Fig. 1). Note that these flows are presented on a calendar year basis, and so differ somewhat from earlier representations of flows that were based upon the water year.

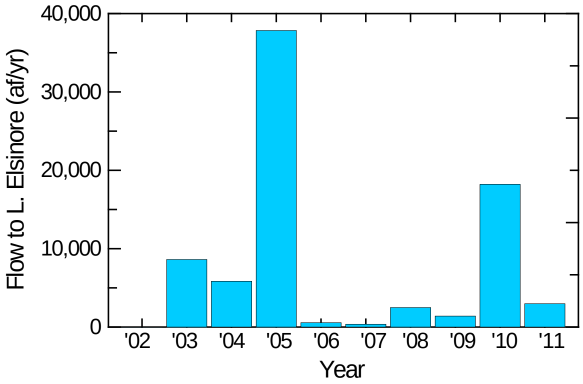


Fig.1. Predicted annual flow (calendar year basis) from Canyon Lake to Lake Elsinore for the period 2002-2011.

The concentrations of nutrients in these flows were used to calculate the predicted annual loading of nitrogen (Fig. 2) and phosphorus (Fig. 3) to Lake Elsinore.

The very high flows in 2005 yielded correspondingly high loads of P to Lake Elsinore, with generally markedly lower loads during the other years (Fig. 2a). Concentrations were predicted to be approximately evenly distribution between readily bioavailable ortho-phosphate phosphorus (PO_4-P) and other forms generally associated with particulate phases (although dissolved organic P would also be included in the particulate fraction represented in these figures). Particulate inorganic P generally comprised only a small part of the P in the overflow from Canyon Lake (data not shown).

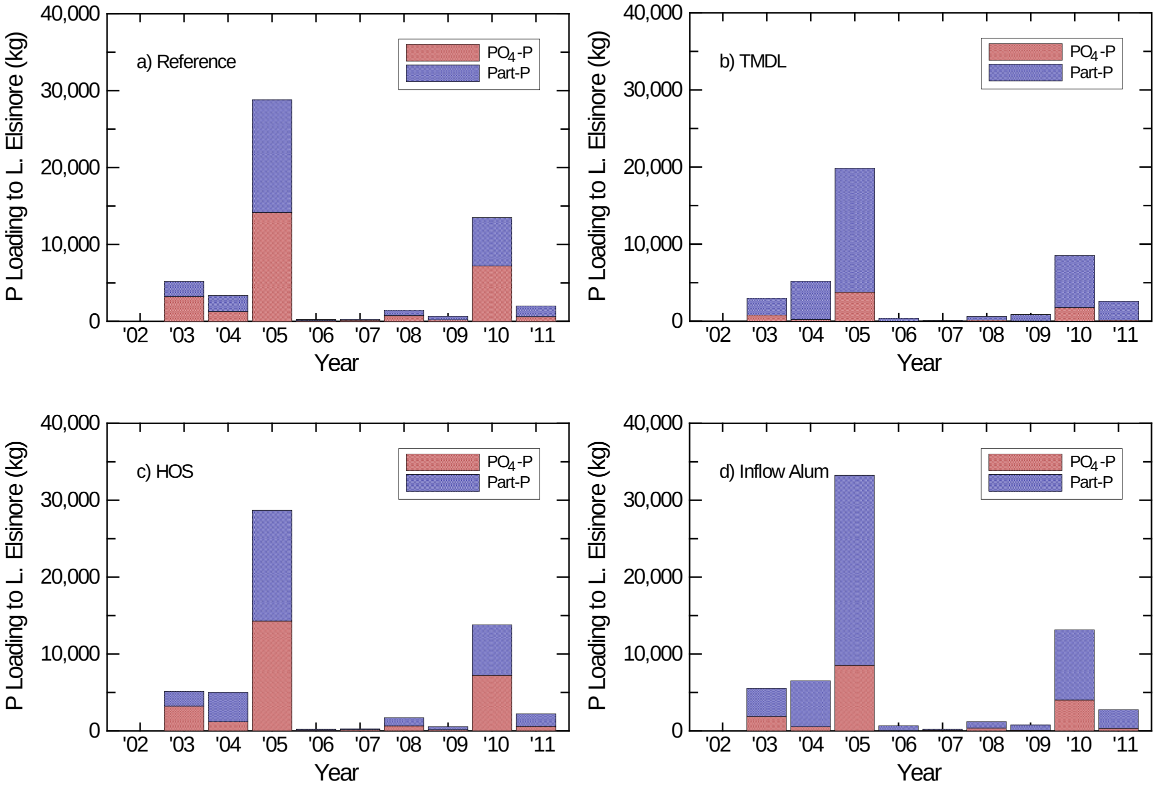


Fig. 2. Predicted loading of P from Canyon Lake to Lake Elsinore for the period 2002-2011: a) reference (existing) condition; b) TMDL-prescribed reductions in external loading; c) operation of HOS; and d) alum treatment of inflows lowering PO_4-P concentrations to 0.2 mg/L.

Implementation of the TMDL-prescribed reductions in total P loading from the watershed not only lowered levels delivered to Canyon Lake (Anderson, 2012c) but also reduced loading to Lake Elsinore (Fig. 2b). Significant reductions in PO_4-P loads exported to Lake Elsinore were predicted that appears to be due to repartitioning of P between dissolved and particulate forms when routed through Canyon Lake relative to the reference (existing) condition. In contrast, operation of the HOS was not predicted to substantively alter the mass or form of P delivered to Lake Elsinore (Fig. 2c). The treatment of inflows with low doses of alum sufficient to modestly lower PO_4-P concentrations in influent to 0.20 mg/L (Anderson, 2012b) was not predicted to greatly alter the mass delivered to Lake Elsinore (and was, surprisingly, predicted to increase it slightly), but was predicted to decrease the amount of PO_4-P delivered to Lake Elsinore. Higher alum doses would presumably further reduce PO_4-P loading and would also promote greater flocculation and settling of particulate P. Irrespective of the particular scenario, these figures support the notion of highly asynchronous loading from the upstream watershed to Lake Elsinore. It is important to note that external loading from the local watershed, which can comprise a significant part of the total external loading during dry years, is not included in these figures and so the total loading would potentially be quite a bit higher for those conditions.

The loading of N exhibited strong interannual variation broadly similar to P, with much of the N delivered in just a few years. A significant fraction of that N was predicted to be delivered as NO_3-N and as a particulate (or dissolved organic) form, while smaller amounts were delivered as NH_4-N (Fig. 3a). TMDL-mandated reductions in external N loading were reflected in loads delivered to Lake Elsinore, with slightly greater predicted removal of particulate-N (Fig. 3b). Other restoration actions that target phosphorus were not predicted to differ substantively from the reference condition (Fig. 3c,d)

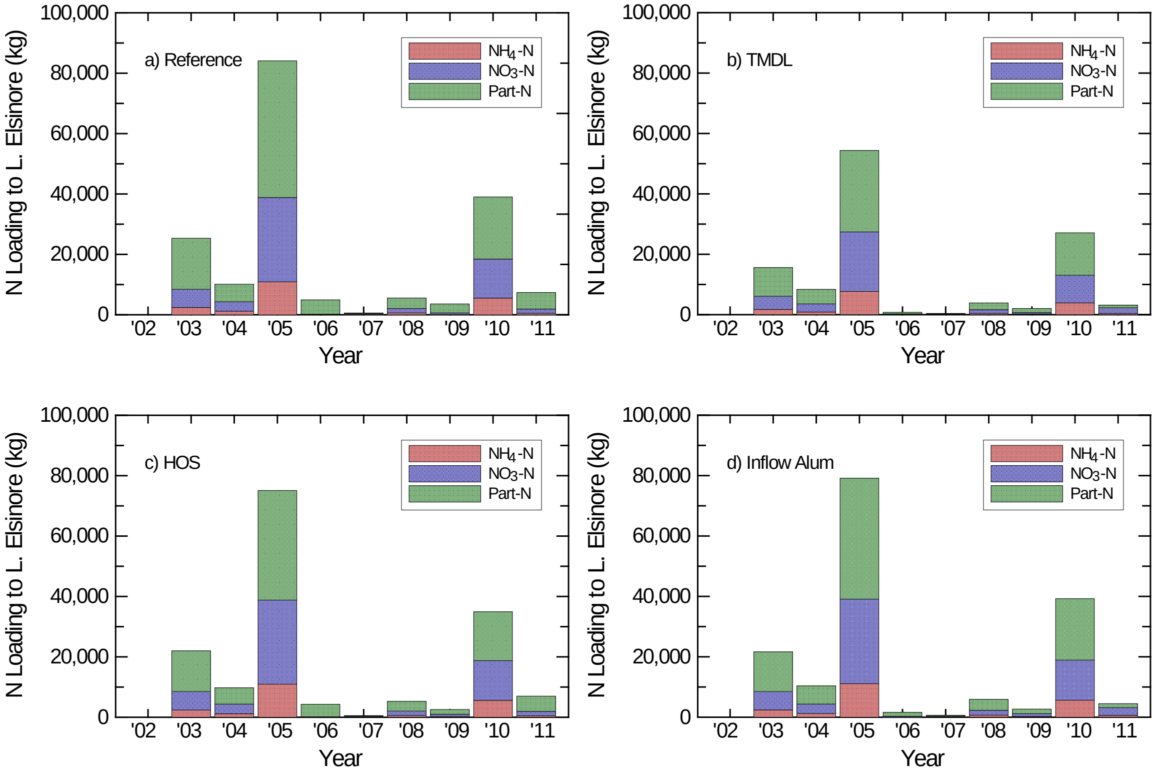


Fig. 3. Predicted loading of N from Canyon Lake to Lake Elsinore for the period 2002-2011: a) reference (existing) condition; b) TMDL-prescribed reductions in external loading; c) operation of HOS; and d) alum treatment of inflows lowering PO_4-P concentrations to 0.2 mg/L.

Conclusions

Results from these analyses indicate:

(i) Strong asymmetric loading of nutrients routed through Canyon Lake to Lake Elsinore during periods of large runoff events.

(ii) TMDL-prescribed external load reductions were predicted to have a greater effect on N and P loading to Lake Elsinore than operation of a hypolimnetic oxygenation system or low levels of alum addition to inflow.

References

Anderson, M.A. 2012a. *Evaluation of Long-Term Reduction of Phosphorus Loads from Internal Recycling as a Result of Hypolimnetic Oxygenation in Canyon Lake.* Draft Technical Memorandum, Task 2, to LESJWA. 21 pp.

Anderson, M.A. 2012b. *Evaluation of Alum, Phoslock and Modified Zeolite to Sequester Nutrients in Inflow and Improve Water Quality in Canyon Lake.* Draft Technical Memorandum, Task 3, to LESJWA. 12 pp.

Anderson, M.A. 2012c. *Evaluate Water Quality in Canyon Lake Under Pre-Development conditions and TMDL-Prescribed External Load Reductions.* Draft Technical Memorandum, Task 4a, to LESJWA. 8 pp.

Task 1: Estimate Rate at Which Phosphorus is Rendered No Longer Bioavailable in Sediments

- Data from Anderson (2001), Anderson and Oza (2003), Anderson et al. (2007) and Anderson (2010) were used to improve understanding of sediment diagenesis in Canyon Lake and Lake Elsinore
- Kinetic modeling conducted to define reactivity and persistence of sediment-bound nutrients available for release from sediments

Table 1. Median water column, particulate and sediment properties in lakes.

	Property	**Canyon L.**	**L. Elsinore**
Water Column	Total N	1.50	3.82
(mg L^{-1})	Total P	0.18	0.22
	N:P Ratio	8.3	17.4
Particulates(Sediment Trap)	Total N	11.1	8.5
(mg g^{-1})	Total P	2.73	1.29
	Organic C	46.5	64.8
	Inorganic C	17.8	14.0
	C:N Ratio	4.2	7.7
	N:P Ratio	4.1	6.6
Sediment (0-10 cm)	Total N	4.4	5.0
(mg g^{-1})	Total P	0.74	0.85
	Organic C	32.6	43.0
	Inorganic C	5.3	9.0
	C:N Ratio	7.4	8.6
	N:P Ratio	5.9	5.9
Loss from Particulates	Total N	6.7 (60%)	3.5 (41%)
(mg g^{-1})	Total P	1.99 (73%)	0.44 (34%)
	Organic C	13.9 (30%)	21.8 (34%)
	Inorganic C	12.5 (70%)	5.0 (36%)

- Median TN:TP values indicate weak N-limitation in Canyon Lake and co-limitation or weak P-limitation in Lake Elsinore when light not limiting
- Particles recovered in sediment traps in Canyon Lake had higher median N and P contents and lower organic C contents and TN:TP ratio than Lake Elsinore
- Lower N:P ratios in particles suggest preferential removal of N during settling and/or resuspension
- Sediments (0-10 cm) had much lower N and P contents that particles recovered in sediment traps, indicating significant loss through recycling and diagenesis
- Greater relative loss in surficial sediments of Canyon L. (60-70%) compared with L. Elsinore (~35-40%)

Table 2. Median particulate flux, internal recycling rate and difference in flux rates.

	Property	**Canyon L.**	**L. Elsinore**
Particulate Flux In	Total Mass	8,220	16,300
(mg m^{-2} d^{-1})	Total N	91	138
	Total P	22.4	21.0
	Organic C	382	1056
	Inorganic C	146	228
	N:P Ratio	4.1	6.6
Nutrient Flux Out	NH_4-N	29.1	86.0
(mg m^{-2} d^{-1})	SRP	9.1	10.2
	N:P Ratio	3.1	8.4
Difference	Total N	62	52
(mg m^{-2} d^{-1})	Total P	13.3	10.8
= storage	N:P Ratio	4.7	4.8

- Assuming sediments are ~80% water with a bulk density of 1.1 g cm^{-3}, these total particle flux rates correspond to sediment rates of 1.4 – 2.7 cm yr^{-1}

- Sediment trap data were used to calculate median particle-borne nutrient deposition rates to sediments
- Very similar particulate-P flux to sediments (~21 mg m^{-2} d^{-1}) in both lakes
- Higher particulate-N, organic C and inorganic C flux to bottom sediments in L. Elsinore
- Similar median rates of SRP flux out of bottom sediments in both lakes (9-10 mg m^{-2} d), but lower NH4-N flux from Canyon L.
- N:P ratio of median recycling/flux rates lower in Canyon L. than L. Elsinore (3.1 vs. 8.4, respectively).

- Differences between particle-borne nutrient flux <u>to</u> sediments and recycling/release <u>from</u> sediments reflect possible storage
- Based upon rates of nutrient flux, similar total N and total P concentrations and N:P ratios would be expected (and are seen) in the two lakes
- Results of all this indicate pronounced biogeochemical transformation occuring within water column and bottom sediments of these lakes
- Kinetic analyses were conducted using available sediment core data to determine rates of these transformations

- Mineralization of organic matter in sediments proceeds through a very complex set of physical, microbiological and chemical reactions

- The rate of mineralization can, in some cases, be represented as a simple 1st-order process:

  $$dC/dt = -kC$$

  where *C* is the concentration, *k* is the decomposition rate constant and *t* is time

- This differential equation can be integrated to:

  $$C=C_0e^{-kt}$$

- Organic matter in sediments is being both mineralized through bacterial processes *and* buried at some sedimentation rate ω

- With information about the sedimentation rate, we can transform from time domain to depth and rewrite as:

$$C_z = C_0 e^{-\frac{k_r}{\omega} z}$$

where k_r is the rate constant for mineralization, and calculated from fit to sediment core nutrient concentrations with depth (k) and sedimentation rate

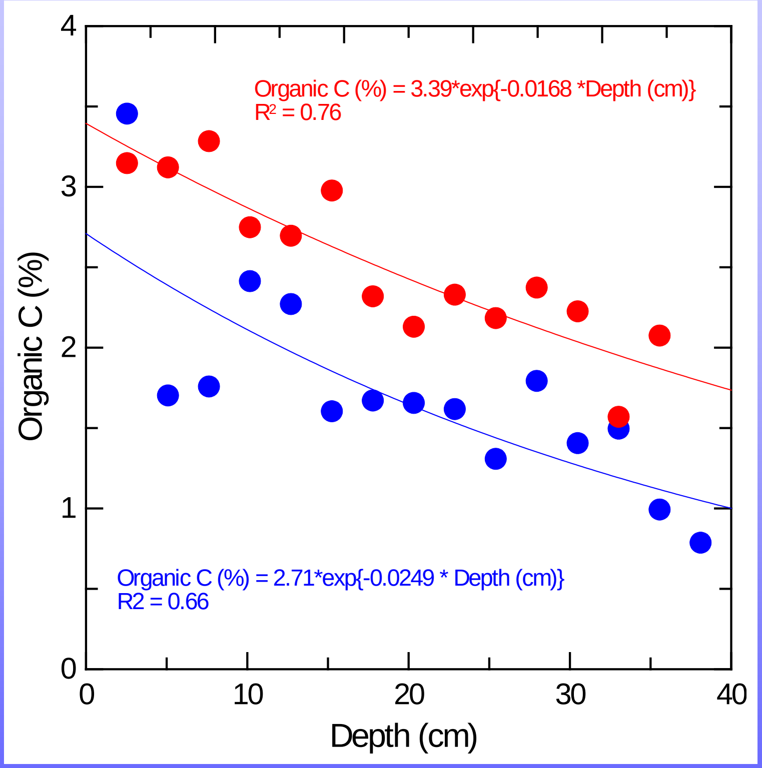
$$k_r = k\ \omega$$

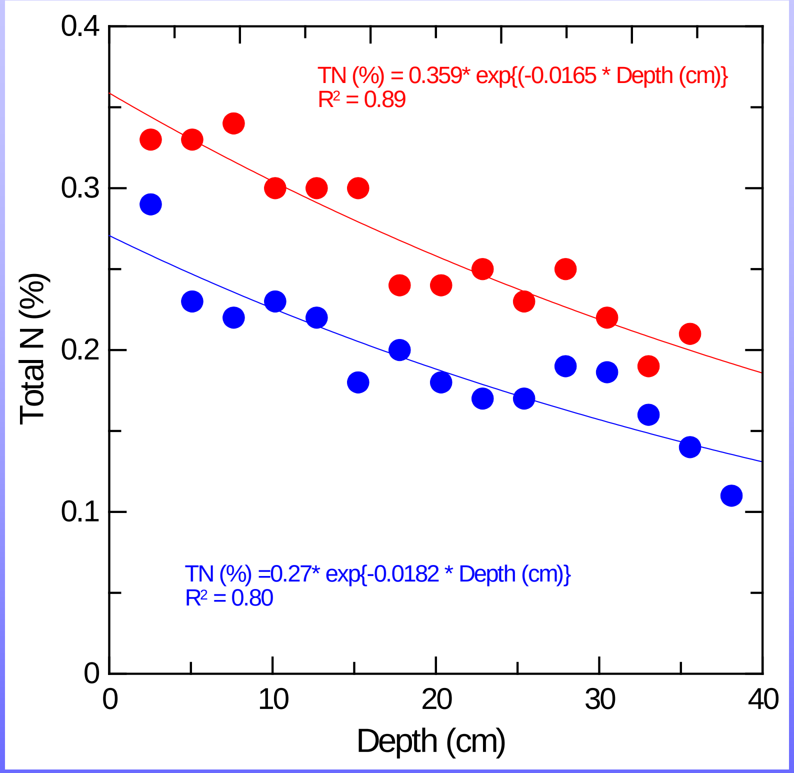
- The half-life for nutrients in the sediment can then be calculated for kr via:

$$t_{1/2} = 0.693/k_r$$

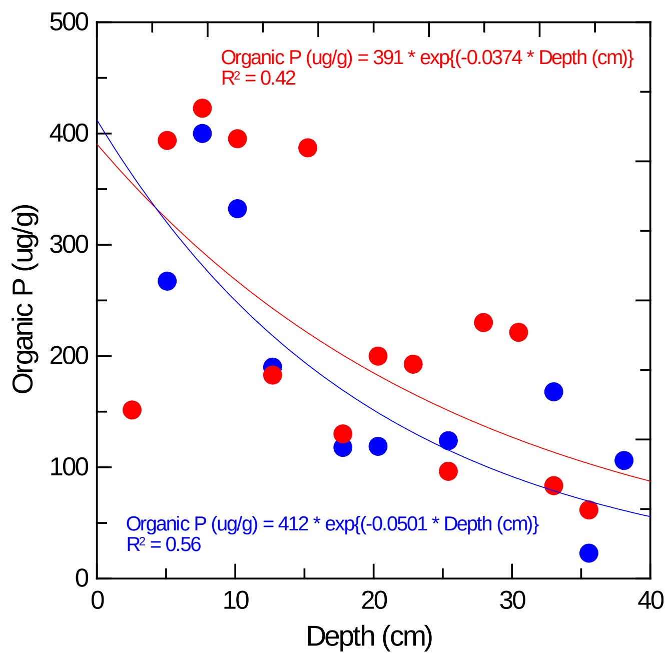
- Sedimentation rates of 2.4 cm yr^{-1} reported by USGS for Canyon L. and 1.35 cm yr^{-1} reported by Kirby et al.

Canyon Lake (East Bay cores, 2002)





- Organic C and total N contents decrease with depth in sediments
- Statistically significant (at p=0.05) for exponential model



- Organic P concentrations exhibited greater scatter and fits not statistically significant
- Half-lives were similar for organic C and N (~14-16 yrs), but lower for organic P (6.7 yrs)

Table 3. Mineralization rate and half-life for organic C, total N and organic P in East Bay, Canyon L.

	k (cm^{-1})	R^2 (n=15)	k_r (yr^{-1})	$t_{1/2}$
Organic C	0.0205 0.0040	0.71 0.05	0.050 0.010	13.9 2.9
Total N	0.0174 0.0008	0.85 0.05	0.042 0.002	16.5 0.8
Organic P	0.0438 0.0064	0.49 0.07	0.105 0.015	6.7 1.0

Lake Elsinore (2001)

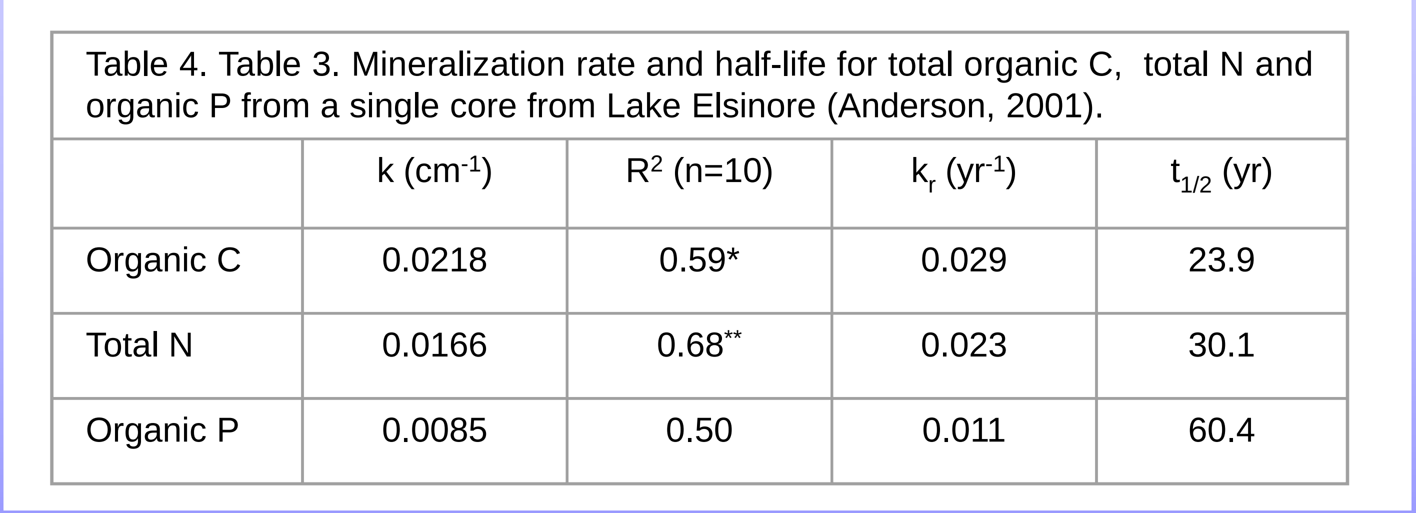


Table 4. Table 3. Mineralization rate and half-life for total organic C, total N and organic P from a single core from Lake Elsinore (Anderson, 2001).

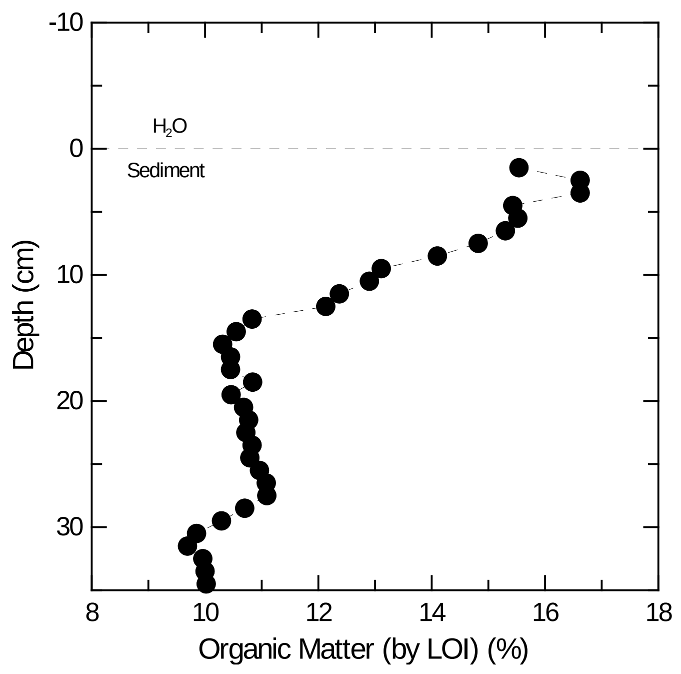
	k (cm^{-1})	R^2 (n=10)	k_r (yr^{-1})	$t_{1/2}$ (yr)
Organic C	0.0218	0.59*	0.029	23.9
Total N	0.0166	0.68**	0.023	30.1
Organic P	0.0085	0.50	0.011	60.4

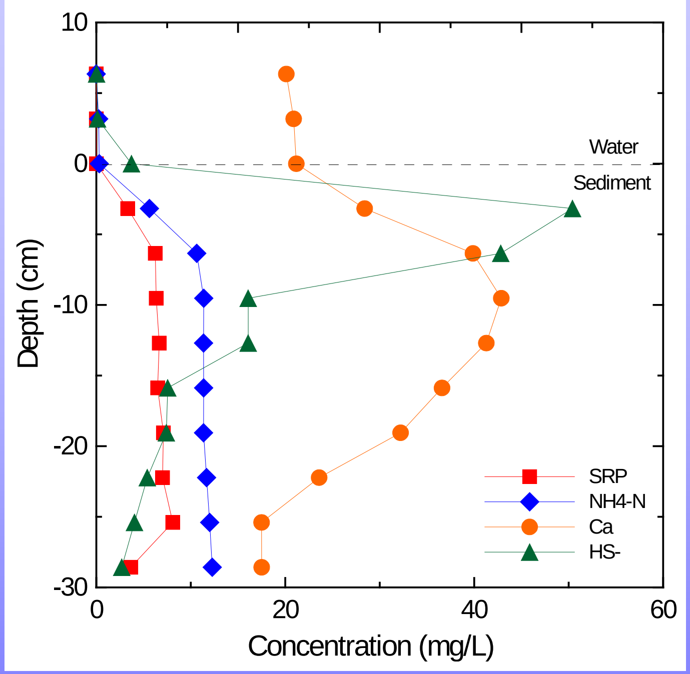
- Lake Elsinore was found to have a slower apparent mineralization rate constant and corresponding (2x) longer nutrient half-lives

- Organic C and N were estimated to have t1/2 values of 24-30 yrs (2x longer than Canyon L.)

- Organic P half-life was 60 yrs or 9x longer than Canyon L.

Two-phase model





- Zone of most rapid loss of organic matter coincides with sulfide in porewater, suggesting that sulfate serves as a 1^o oxidant in sediments in L. Elsinore
- Core from Kirby et al. indicates organic matter (LOI) persists within buried sediment

- Organic matter often consists of or degrades to a recalcitrant phase that undergoes very slow further mineralization
- We can model the sediments as a 2-phase system with a rapidly reacting organic matter and slow or negligibly reactive phase as:

$$C_z = C_0 e^{-\frac{k_r}{\omega} z} + C_u$$

- It is assumed here than the unreactive phase at concentration C_u undergoes no reaction
- A nonlinear least-squares analysis for 3 unknowns (k_r, C_0 and C_u) was conducted

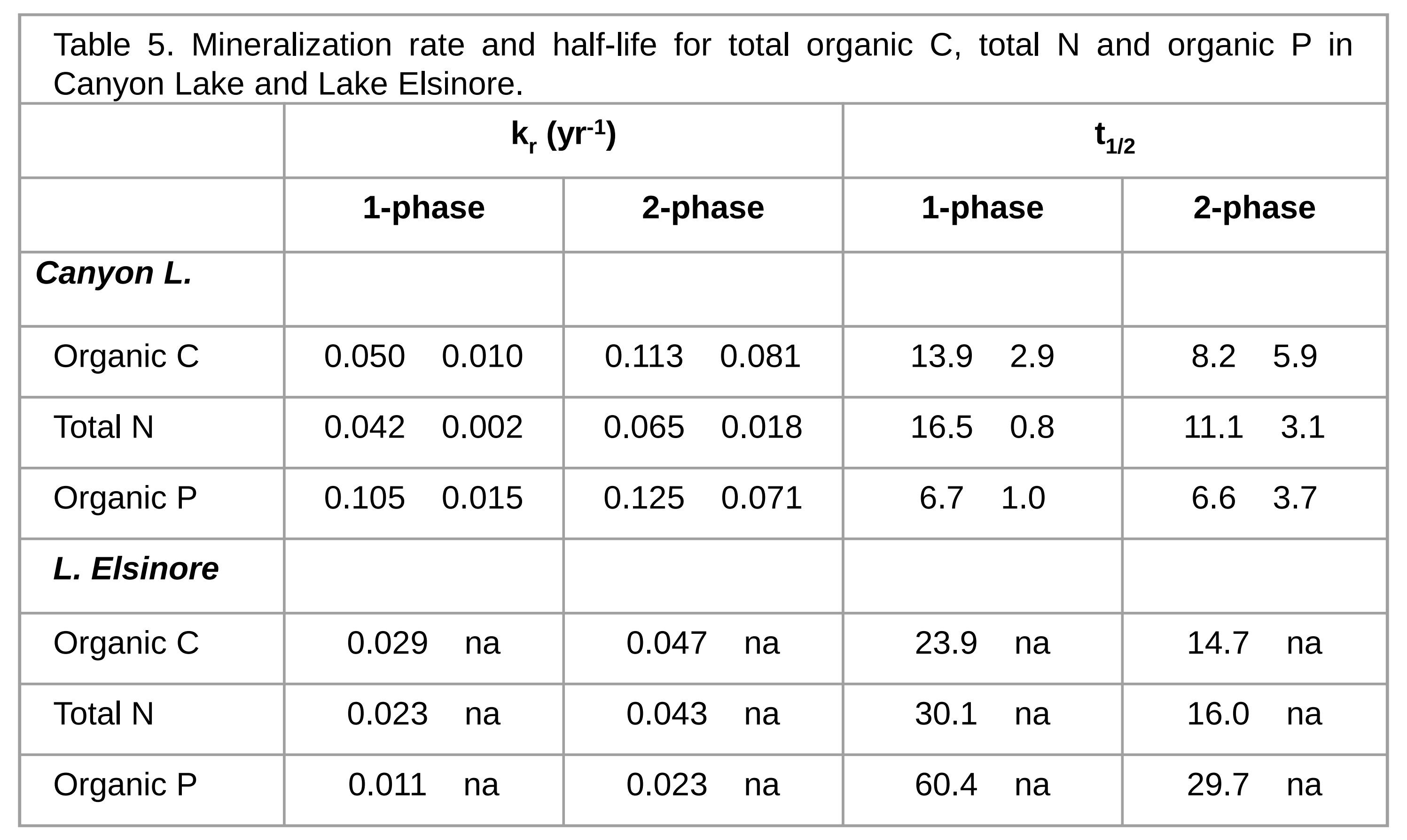
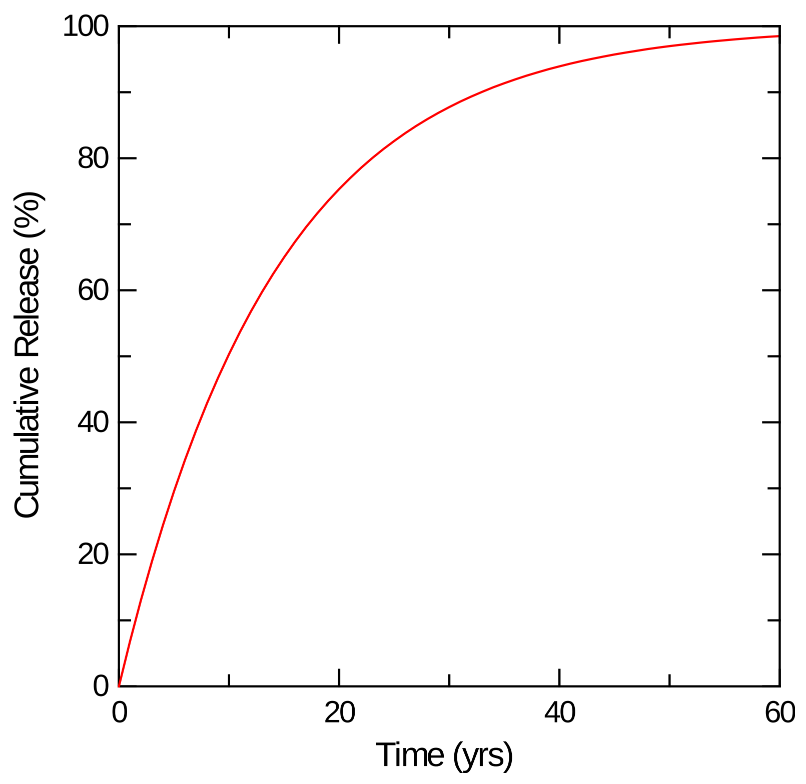
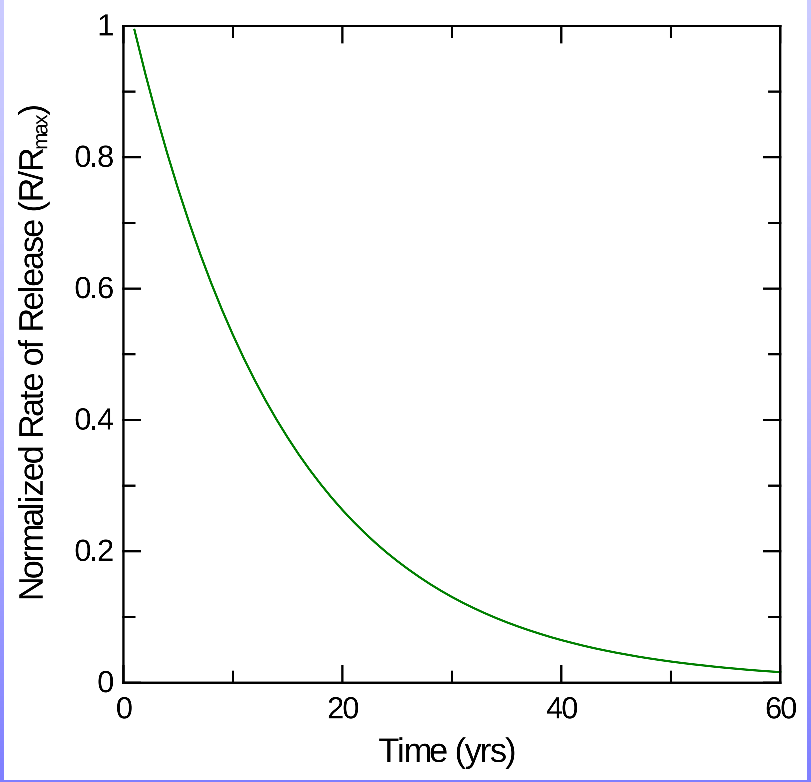


Table 5. Mineralization rate and half-life for total organic C, total N and organic P in Canyon Lake and Lake Elsinore.

	k_r (yr^{-1})		**$t_{1/2}$**	
	1-phase	**2-phase**	**1-phase**	**2-phase**
Canyon L.				
Organic C	0.050 0.010	0.113 0.081	13.9 2.9	8.2 5.9
Total N	0.042 0.002	0.065 0.018	16.5 0.8	11.1 3.1
Organic P	0.105 0.015	0.125 0.071	6.7 1.0	6.6 3.7
L. Elsinore				
Organic C	0.029 na	0.047 na	23.9 na	14.7 na
Total N	0.023 na	0.043 na	30.1 na	16.0 na
Organic P	0.011 na	0.023 na	60.4 na	29.7 na

- The 2-phase model yielded higher k_r values and shorter half-lives than the 1-phase model
- This indicates that half-lives of nutrients in Canyon L. and L. Elsinore are ~10 and 15 yrs, respectively





- With a half-life of ~10 yrs for Canyon L., by definition ~50% of the nutrients have been released from the sediments in 10 yrs
- After 30 yrs, only about 15% remain, with very slow rate of release

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Technical Memorandum

Task 2: Evaluation of Long-Term Reduction of Phosphorus Loads from Internal Recycling as a Result of Hypolimnetic Oxygenation in Canyon Lake

Objective

The objective of this task was to evaluate the long-term reduction in internal nutrient recycling from bottom sediments and water quality that would result from installation and operation of a hypolimnetic oxygenation system at Canyon Lake.

Approach

The DYRESM-CAEDYM model was used to predict water quality over a 10-yr time horizon. The period January 2002 – December 2011 was selected since a number of studies have been conducted at the lake and watershed over this time period, meteorological and flow data are available, and a wide range in precipitation regimes were present, including drought (2002, 2007-2009) and near-record rainfall (2005). The previous parameterization of the model (Anderson, 2007; Anderson, 2008) was used as the starting point for this modeling effort. The availability of monitoring data and related field studies allow for robust verification and use of the model over this extended period of time. Three (3) different scenarios were evaluated: (i) a reference scenario that reflected conditions present in the lake and watershed; (ii) a scenario in which no internal recycling of nutrients occurred, and thus predicted water quality subject only to external loading to the lake (this would thus represent the *theoretical best* water quality attainable through in-lake treatment); and (iii) hypolimnetic oxygenation of the lake following PACE design 10b.

Meteorology

The meteorological conditions for 2002-2011 as measured at the CIMIS station at UCR (CIMIS #44) were used in all simulations. Daily average values for shortwave solar radiation, air temperature, and rainfall were used as part of the input data used to drive the thermodynamic-hydrodynamic model (DYRESM) (Fig. 1). Daily average shortwave radiation flux (J_{sw}) exhibited a well-defined seasonal trend, with daily winter values generally 100-150 W m^{-2} and summer maximum values of about 350 W m^{-2} (Fig. 1a). Day-to-day variations were nonetheless apparent and result from absorption and scattering of the incoming solar radiation by the atmosphere, especially cloud cover. On particularly cloudy winter days, the shortwave solar radiation averaged over the 24-h period often dropped below 50 W m^{-2} (Fig. 1a) and resulted in net cooling of the water surface and/or low equilibrium temperatures in the lake.

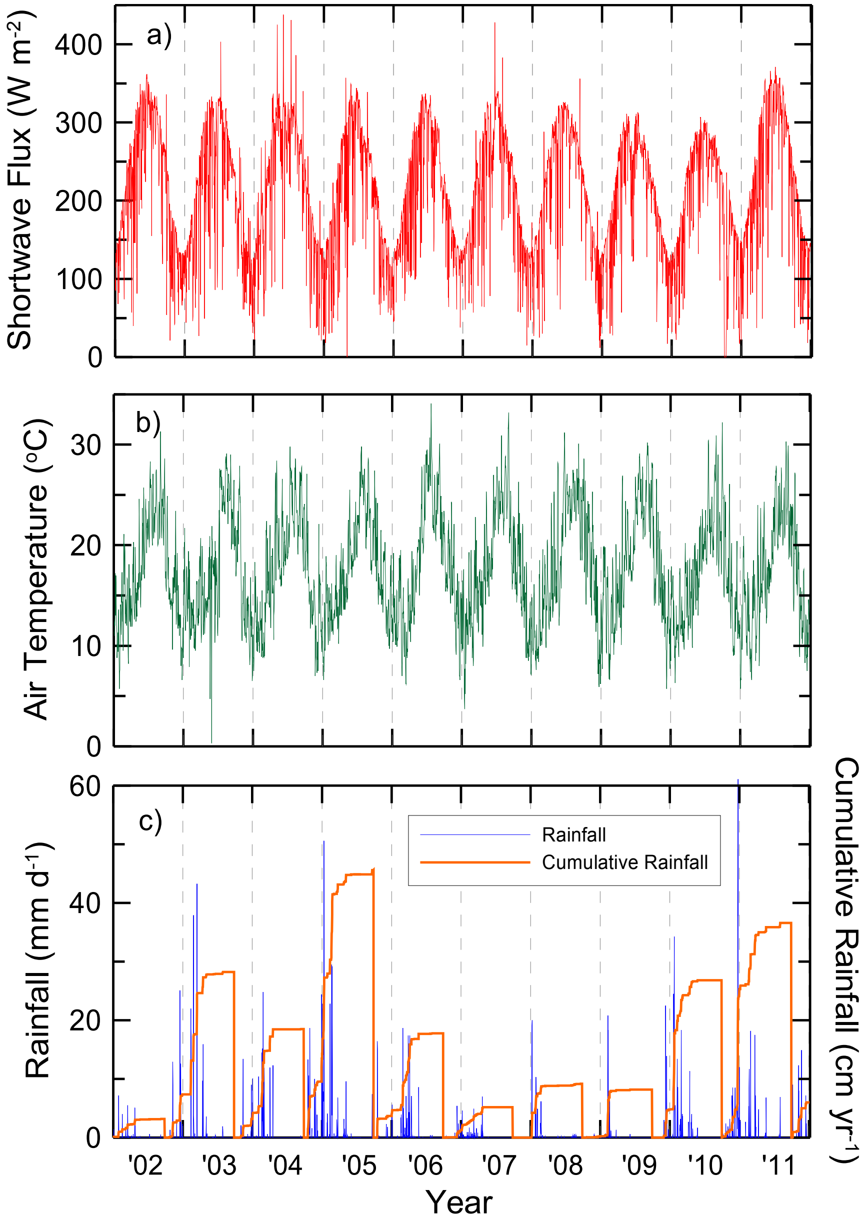

Fig. 1. Key meteorological data used to drive hydrodynamic-thermodynamic DYRESM model.

Daily average air temperatures exhibited strong seasonal trends as well (Fig. 1b). Daily values were typically around 10-12 ºC in the winter and 25-30 ºC in the summer. The atmosphere contributes longwave (>3000 nm wavelength) heat flux (J_l) to the lake (calculated from temperature and cloud cover) that, combined with shortwave heat flux, constitute the principal heat inputs to the lake (eq 1):

$$J_{net} = J_{sw} + J_l - (J_{br} + J_e + J_c) \qquad (1)$$

where J_{net} is the net heat flux, J_{br} is back radiation, J_e is evaporative heat flux and J_c is convective heat flux. Several processes thus also result in *release* of heat from the lake. For example, back-radiation from the water surface (J_{br}) that is related to the surface water temperature, following the Stefan-Boltzmann law, exports a significant amount of heat, as does evaporative heat flux (J_e). Evaporative heat flux is especially important in this region, where very warm dry conditions, often combined with strong winds, can export a substantial amount of heat (2.3 kJ g^{-1} water evaporated). DYRESM also requires information about windspeed and humidity in the air (not shown).

While these meteorological parameters define the net heat flux to the lake and the mixing that results from wind shear on the water surface, rainfall is part of the water balance calculation:

$$\frac{dV}{dt} = \sum_i Q_i + PAs - (EAs + W + Q_{out}) \qquad (2)$$

where V is lake volume, t is time, Q_i is the daily flow rate of inflow I, P is the precipitation rate, As is the lake surface area, E is evaporation rate, W is the withdrawal from the lake by EVMWD, and Q_{out} is overflow to Lake Elsinore.

Rainfall varied markedly over the 10-yr period, with daily events ranging from <0.1 mm d^{-1} to >50 mm d^{-1} (blue lines, Fig. 1c). Rainfall was most abundant in the winter, with very strong differences in the total annual (based on water year) rainfall values that ranged from <5 cm (2002) to 45.7 cm (2005) (Fig. 1c). Rainfall directly on the lake surface is generally only a very small contribution to the water budget, although precipitation on the watershed that results in inflow (Q_i) can be very substantial (Fig. 2). Runoff to the lake was taken from USGS gaging stations for the San Jacinto River and Salt Creek near Sun City (USGS #11070365 and #11070465, respectively). The very high amount of rainfall in WY 2005 resulted in runoff events at the beginning of the year with flows in SJR >2500 cfs; in contrast, very little SJR flow was recorded in 2002 and 2006 (Fig. 2a). Generally substantially lower flow rates were present in Salt Creek (Fig. 2b).

Evaporation was determined from temperature (Fig. 1b), humidity (vapor pressure) and wind speed (not shown); it is widely recognized that evaporation removes 1.4-1.5 m of water from the lake surface each year. Detailed records on withdrawals by EVMWD for water treatment and distribution were provided by Julius Ma (EVMWMD). The final component of the water budget is that of overflow (O) that was calculated from water balance and information about lake hypsography and dam crest height. DYRESM dynamically calculated the heating of the water column (eq 1), wind mixing, and water budget (eq 2) over the 10-yr simulation period using a 60 min time step.

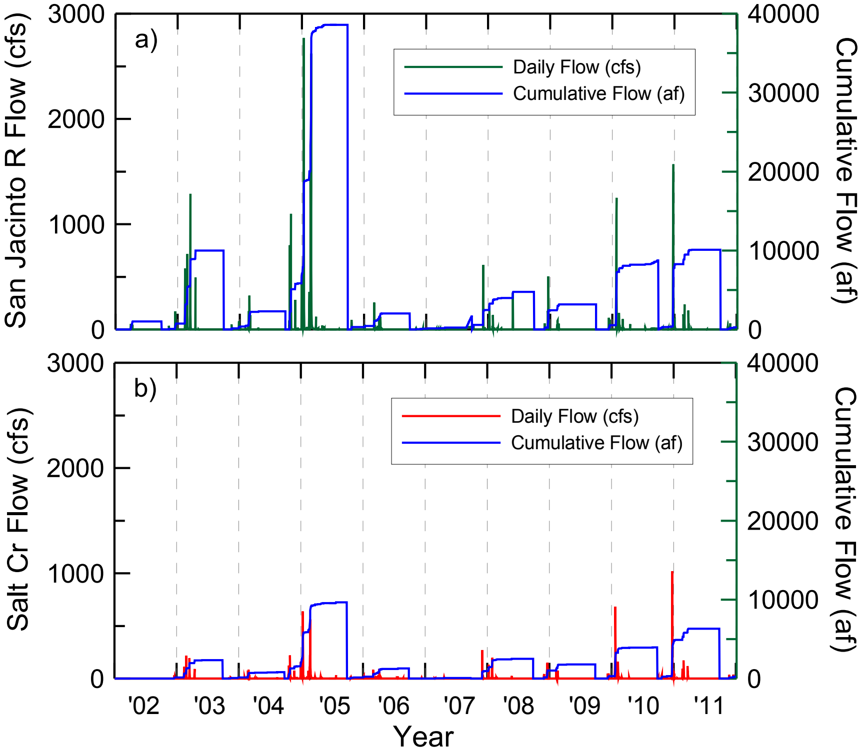

Fig. 2. Daily and cumulative flows to Canyon Lake from a) San Jacinto River and b) Salt Creek.

The model was also used to simulate water quality, including concentrations of nutrients, chlorophyll a, and dissolved oxygen (DO), as well as water transparency and pH and other properties. The model thus solves mass balance equations for each constituent that includes inputs associated with streamflow, recycling within the lake, atmospheric deposition (for N and P), as well as chemical, microbial and biological transformations, and losses via sedimentation and export (from overflow to Lake Elsinore and withdrawal of water by EVMWD).

The input of nutrients from external loading, especially associated with flows into Canyon Lake from San Jacinto River and Salt Creek (Fig. 2), is thus a critical part of the model calculations. Statistical analysis of the measured water quality at the TMDL sampling stations on the San Jacinto River and Salt Creek (2001-2010) yielded mean, geometric mean and median influent concentrations (Table 1). Median values were used as input for the model.

Rates of internal loading of nitrogen and phosphorus to the water column were calculated dynamically in the model based upon DO, temperature, and pH from rates measured in laboratory core-flux studies (Anderson, 2007a). The rates of NH_4-N and SRP release from bottom sediments were thus reduced with increased DO concentrations above the sediments from rates measured under anoxic conditions. Flux rates measured in 2001-2002 were used as the reference flux rates (Anderson, 2002). Sediment oxygen demand was also specified in the model using results from measurements conducted in 2006-2007 (SOD values of about 0.3 g/m^2/d, with modest difference between sites and dates) (Anderson, 2007a).

Table 1. Statistical analysis of watershed sampling data for San Jacinto River and Salt Creek.

Constituent	**Source**	**Mean**	**Geomean**	**Median**
NH_4-N	Salt Creek	0.39	0.32	0.30
	San Jacinto R	0.45	0.30	0.24
NO_3-N	Salt Creek	0.70	0.63	0.56
	San Jacinto R	0.74	0.59	0.61
TKN	Salt Creek	1.70	1.48	1.45
	San Jacinto R	1.83	1.56	1.60
PO_4-P	Salt Creek	0.44	0.39	0.39
	San Jacinto R	0.45	0.36	0.32
Total P	Salt Creek	0.70	0.58	0.57
	San Jacinto R	1.00	0.80	0.80
TSS	Salt Creek	153	105	88
	San Jacinto R	316	207	220

Results

External Loading

Modeling of the 10-yr period of time from 2002-2011 required daily meteorological data as well as information about inflow. It was thus helpful to first consider the hydrologic loading to the reservoir over this time interval. The individual rainfall events in Fig. 2 were summed within each water year (October 1 – September 30) and clearly show the bulk of the precipitation and runoff occurs near the end of the calendar year/beginning of the following year (x-axis shown as calendar year, so dashed lines correspond to beginning/end of each calendar.) One notes dramatically different total inflows to Canyon Lake (Fig. 3). Water year 2007 generated almost no runoff to the lake (1783 af), while the near-record rainfall in WY 2005 produced almost 50,000 af delivered to Canyon Lake from the San Jacinto River and Salt Creek (Fig. 3).

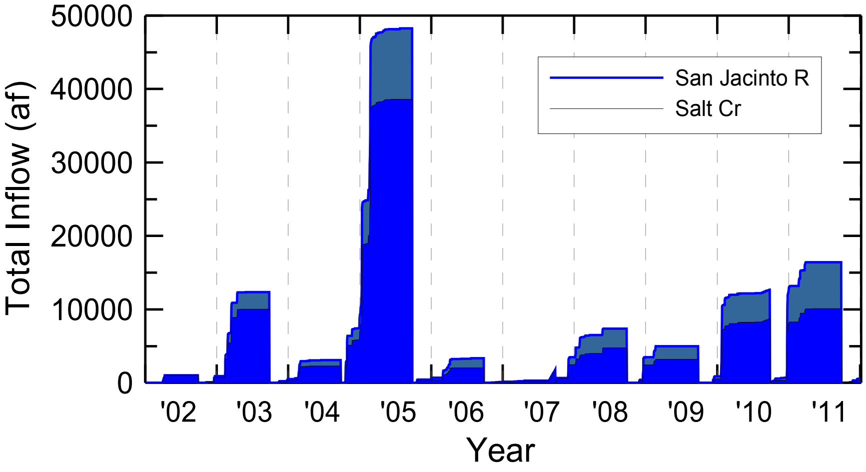

Fig. 3. Cumulative annual inflows to Canyon Lake by water year.

These very large flows also delivered more than 120,000 kg of N and 45,000 kg of P to the lake (Fig. 4). External loading in other years were generally much lower but still significant and associated with winter runoff events (Fig. 4; Table 3).

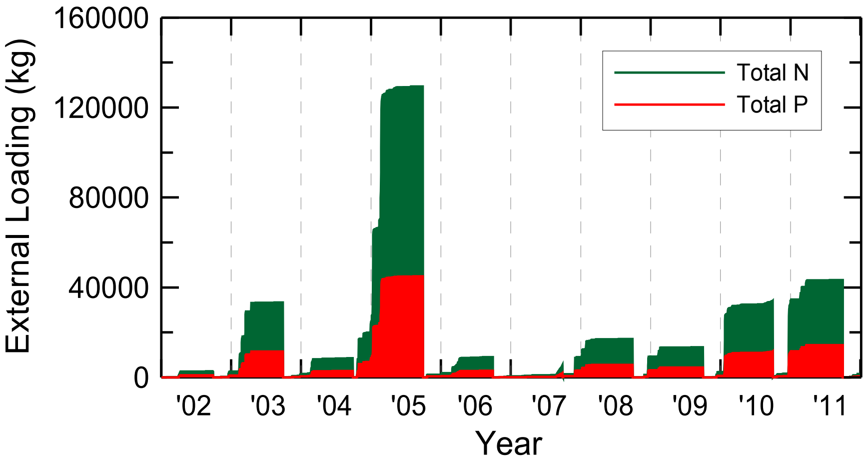

Fig. 4. Cumulative total external loading of N and P to Canyon Lake by water year.

This large volume of flow in 2005 displaced the entire volume of Canyon Lake about 5x, delivered a tremendous amount of nutrients, and effectively reset the water quality and biogeochemistry of the lake. For example, core-flux measurements made in 2006-07 yielded SRP and NH_4-N release rates that were about 60% larger than those found in 2001-02 (Anderson et al., 2007) (Table 2) that resulted from the associated very large external loading of nutrients in 2005 (Fig 4).

Table 2. Average nutrient internal recycling rates in Canyon Lake (Anderson 2002; Anderson et al., 2007).

Year	SRP Flux ($mg\ m^{-2}\ d^{-1}$)	NH_4-N Flux ($mg\ m^{-2}\ d^{-1}$)
2001-02	9.4	25.8
2006-07	15.7	44.1

This external loading can be expressed on an areal basis for comparison with internal loading rates; expressed in this way, the gross external loading of nutrients to Canyon Lake, while quite low during intervals of limited runoff (e.g., 2002, 2007), is often comparable to that due to internal loading (Table 3).

Table 3. Gross external loading of N and P to Canyon Lake.

Water Year	Total N Load (kg)	Total P Load (kg)	Total N Load ($mg\ m^{-2}\ d^{-1}$)	Total P Load ($mg\ m^{-2}\ d^{-1}$)
2002	2,635	965	4.7	1.7
2003	33,277	11,520	58.8	20.4
2004	8,470	2,835	15.0	5.0
2005	129,402	44,887	228.8	79.4
2006	9,002	2,933	15.9	5.2
2007	5,367	1,857	9.5	3.3
2008	17,028	5,616	30.1	9.9
2009	13,339	4,409	23.6	7.8
2010	33,982	11,462	60.1	20.3
2011	43,280	14,366	76.5	25.4

A portion of those externally loaded nutrients (as well as internally loaded nutrients) will be exported from the lake during flows sufficient to over-top the dam and to a lesser extent, with withdrawals by EVMWD, however. Outflows to downstream San Jacinto River and Lake Elsinore predictably varied with runoff conditions, with almost all runoff to the lake in 2005 spilling to Lake Elsinore (Fig. 5). Significant outflows from the lake were also seen in 2003, 2010 and 2011, while no flows were predicted (nor observed) in 2002 and 2007.

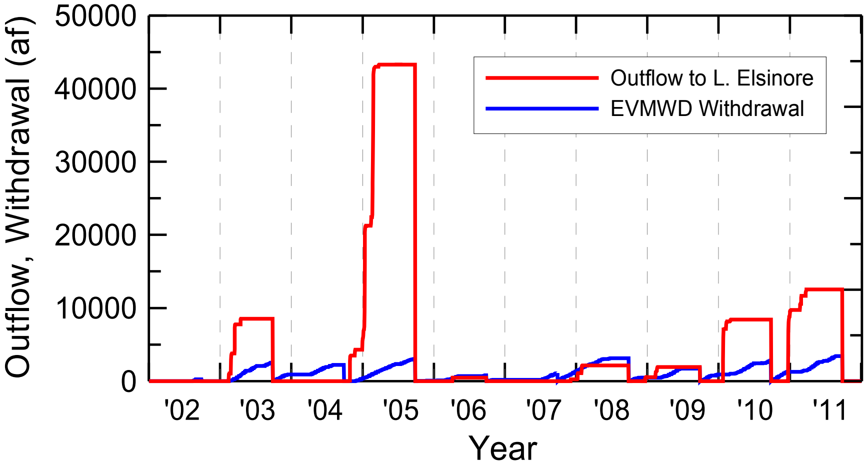

Fig. 5. Cumulative water removal from Canyon Lake via overflow from dam and EVMWD withdrawal by water year.

The water spilled over the dam (and the relatively small volumes withdrawn by EVMWD) removed nutrients from the lake. The gross external loads of total N and total P can be compared with those exported via outflow and withdrawal (Fig. 6). As one can see, years with outflow (Fig. 5) did export total N and P from the lake, up to about 10,000 kg of total P and 20,000 kg of total N in 2005, but only a modest proportion of the gross external load was exported (Fig. 6). Canyon Lake, as modeled in this reference scenario (no hypolimnetic oxygenation system or other in-lake management strategies implemented), thus has finite capacity to retain runoff and storm flows, but is generally quite effective at retaining nutrients.

The annual retention of N and P in Canyon Lake is summarized in Table 4. Phosphorus was generally retained more effectively than N, with an average net retention of P of 84.9%, compared with 68.2% for N. Expressed as % transported (15.1% and 31.8% for P and N respectively), we see that Canyon Lake is on average twice as effective at retaining P than N. Nonetheless, the % nutrients retained did vary from year to year that appeared to be a complex function of amount of water retained and, more importantly, the duration and timing of the inflows. Storms that quickly flushed through the lake would provide little residence time of water and thus result in limited opportunity for settling of particulate forms of nutrients, uptake, and biological transformation reactions. Conversely, flows and nutrient inputs from a series of storms over much of the winter would provide time for reaction and potentially greater in-basin removal.

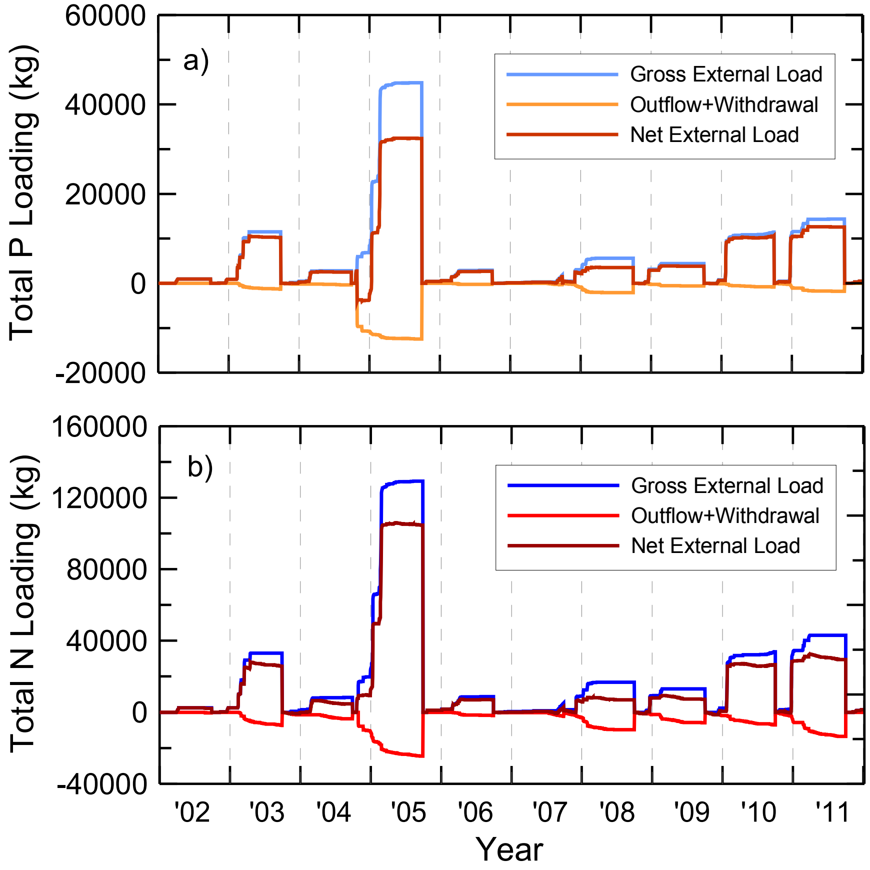

Fig. 6. Cumulative nutrient budgets for Canyon Lake by water year: a) total P and b) total N.

Table 4. Retention of inflow and externally loaded nutrients in Canyon Lake by water year.

Water Year	**Water Volume Retained (af)**	**Total P Retained (kg)**	**Total N Retained (kg)**
2002	814 (78.3%)	944 (97.1%)	2,162 (86.0%)
2003	1,225 (9.9%)	10,222 (88.7%)	25,730 (77.8%)
2004	871 (28.0%)	2,489 (87.8%)	4,667 (56.4%)
2005	1,998 (4.1%)	32,398 (72.2%)	104,679 (81.0%)
2006	2,807 (62.4%)	2,664 (90.8%)	7,033 (79.9%)
2007	706 (39.6%)	1,526 (82.2%)	2,932 (56.7%)
2008	4,237 (57.6)	3,501 (62.3%)	7,007 (41.6%)
2009	1,290 (25.9%)	3,806 (86.3%)	7,200 (54.8%)
2010	4,278 (33.7%)	10,620 (92.6%)	26,647 (78.9%)
2011	466 (2.8%)	12,571 (88.5%)	29,535 (68.6%)

Correcting for nutrients exported from the basin, we see that external loading expressed as a flux rate (Table 5) remains comparable to or exceeds the annual average internal recycling rate (Table 2) in 4 out of 10 year.

Table 5. Net external loading of N and P to Canyon Lake.

Water Year	**Net Total N Load (kg)**	**Net Total P Load (kg)**	**Total N (mg m^{-2} d^{-1})**	**Total P (mg m^{-2} d^{-1})**
2002	2,266	937	4.0	1.7
2003	25,890	10,218	45.7	18.1
2004	4,777	2,489	8.5	4.4
2005	104,816	32,408	185.3	57.3
2006	7,193	2,663	12.7	4.7
2007	3,043	1,526	5.4	2.7
2008	7,084	3,499	12.5	6.2
2009	7,310	3,805	12.9	6.7
2010	26,812	10,614	47.4	18.8
2011	29,690	12,714	52.5	22.5

Simulation #1: Reference Condition

DYRESM-CAEDYM was used to simulate water quality in Canyon Lake subject to the above meteorological and runoff conditions under the natural conditions in the lake (i.e., with no hypolimnetic oxygenation or other in-lake restoration efforts). As we have seen in previous simulations, the model predicted strongly stratified conditions in Canyon Lake through much of the year, with epilimnion temperatures exceeding 25 ºC and with much cooler temperatures in the hypolimnion, generally 10-12 ºC (Fig. 7a). The multi-year record simulated here demonstrated that there is some year-to-year variation in the hypolimnion temperature related to specific meteorological conditions present when stratification sets up in the early spring (Fig. 7a).

The model predicted high DO concentrations in the epilimnion in the summer and through much of the water column during the winter mixing condition, although the extent of mixing of DO varied from year-to-year, with weaker predicted mixing in early winter 2005 and 2011 and complete mixing in early winter 2007 (Fig. 7b).

Total N and total P concentrations also exhibited strong seasonal and vertical differences. Rapid development of anoxia in the hypolimnion promoted reductive dissolution of $Fe(OH)_3$-H_2PO_4 sorbed phases as well as mineralization of organic-N and organic-P phases resulting in internal loading of NH_4-N and PO_4-P to the water overlying the bottoms sediments (Fig. 7c,d). Total N (principally as NH_4-N) reached concentrations of 4-5 mg/L above the bottom sediments in the fall, while concentrations in the epilimnion were more typically 1-1.4 mg/L (Fig. 7c).

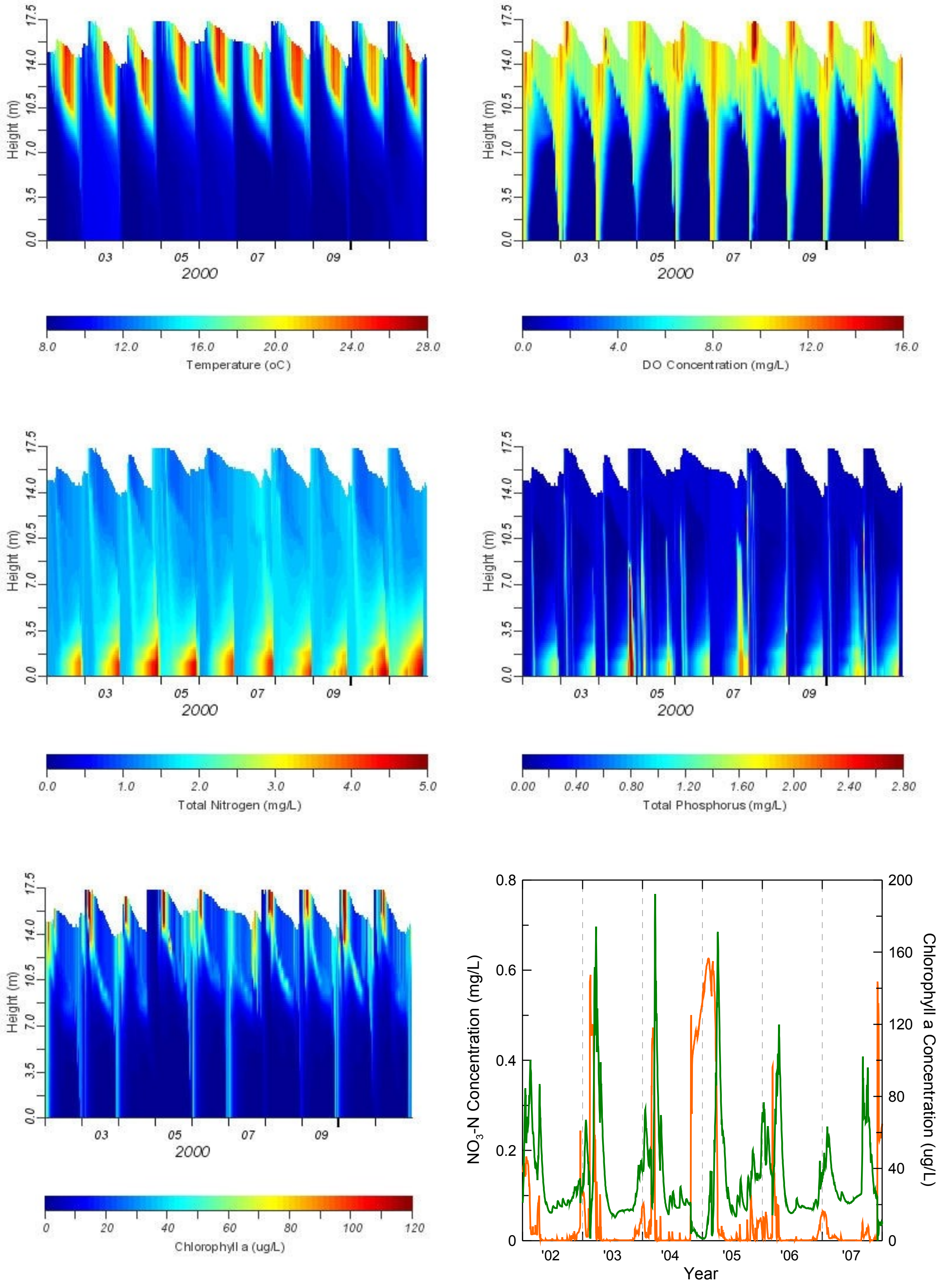

Fig. 7. Predicted water column conditions and water quality in Canyon Lake under reference scenario: a) temperature, b) DO, c) total N, d) total P, e) chlorophyll a, f) NO3+chlroophyll a.

Similar trends were seen for total P (principally as PO_4-P), with concentrations near 2 mg/L above the bottom sediments in the fall prior to mixing, although higher concentrations were seen in 2005 following the very large input of particulate inorganic P (Fig. 7d). Total P concentrations were generally much lower in the epilimnion (0.2-0.4 mg/L). Finally, chlorophyll a concentrations exhibited particularly strong seasonal and vertical differences. Very high concentrations were present in the epilimnion in the winter-spring, often exceeding 100 µg/L, while concentrations were predictably much lower deeper in the lake owing to light limitations (Fig. 7e). Mixing did distribute some phytoplankton with depth however. Simulations indicate that it is the availability NO_3-N that promotes or limits algal production in the lake, consistent with previous algal nutrient bioassays (Fig. 7f).

Simulation #2: No Internal Loading

The theoretical limit for in-lake restoration efforts aimed at reducing internal recycling would be complete elimination of all internal loading through, e.g., alum application combined with zeolite to remove all PO_4-P and NH_4-N release from bottom sediments. While complete suppression of internal recycling is not possible in reality, it is nonetheless useful to explore water quality in Canyon Lake due only to external loading. As we have seen, a substantial external load of nutrients is delivered to the lake with some frequency (e.g., Fig. 4). For this simulation, then, internal loading of both N and P was set to 0, while all other conditions were held unchanged from the reference simulation described above.

As expected, internal loading did not have a noticeable effect upon temperature or thermal structure in Canyon Lake (Fig. 8a) since this is regulated chiefly by meteorological conditions (Fig. 1). Moreover, the absence of internal loading had little effect on DO concentrations; significant photosynthetic production of DO was still observed in the upper part of the water column, and anoxia was present for much of the year in the hypolimnion (Fig. 8b). More dramatic effects were witnessed for N and P (Fig. 8c,d). Total N did not accumulate above the bottom sediments although concentrations in the upper water column were only modestly reduced (Fig. 8c). In a similar way, total P concentrations generally remained uniformly low throughout the water column, although the externally loaded P that included some particulate forms were evident and reached high concentrations for a period of time during large runoff events (especially winter 2004-2005, late fall 2007, and winter 2010-11) (Fig. 8d). The elevated concentrations deeper in the water column resulted from an “underflow” condition wherein the inflowing water was colder and more dense that the lake, and thereby plunged deeper in the water column. Chlorophyll a concentrations (Fig. 8e) appeared to be modestly reduced, but were not dramatically altered relative to the reference case (Fig. 7e)

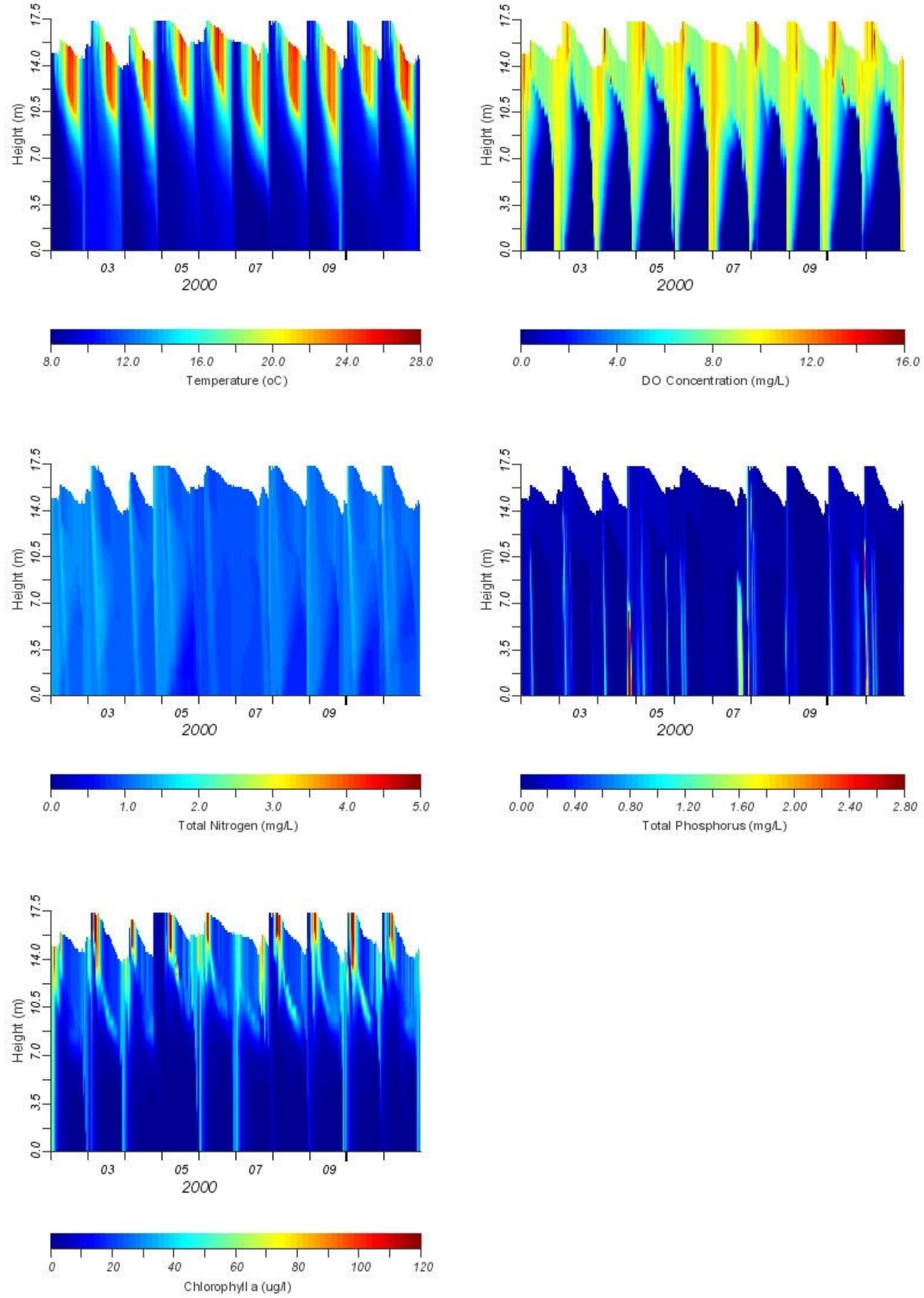

Fig. 8. Predicted water column conditions and water quality in Canyon Lake under no internal loading scenario: a) temperature, b) DO, c) total N, d) total P and e) chlorophyll a.

The effect of no internal loading can be seen more clearly when compared with concentrations at specific depths (Figs. 9-11). We thus see that with internal loading, the concentrations of total N (Fig. 9) and total P (Fig. 10) increased through the spring and summer, and then generally decreased (especially noticeable for the bottom depths (panel b on Figs. 9-10). An increase in concentrations in the surface waters in both scenarios was often seen in the winter as a result of external loading. Lower concentrations were consistently present in the simulation with no internal loading, reflecting the reduction in total loading to the water column. Very similar behavior was seen for both total N (Fig. 9) and total P (Fig. 10).

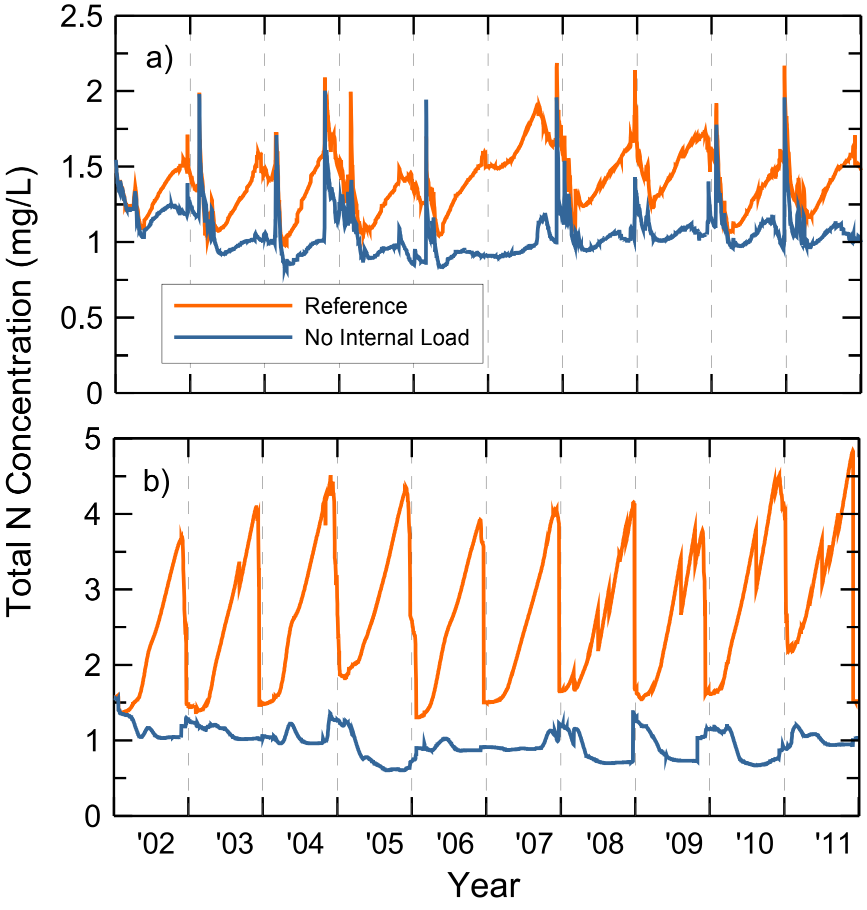

Fig. 9. Predicted total N concentrations comparing the reference scenario with the no-internal loading scenario: a) 1 m below surface and b) 1 m above bottom sediments.

The absence of internal loading did result in somewhat lower chlorophyll concentrations in the epilimnion, although peak concentrations following external loading (especially of NO_3-N) were broadly similar (Fig. 11). Thus, even with no internal loading, chlorophyll a concentrations were predicted to remain relatively high (Fig. 11).

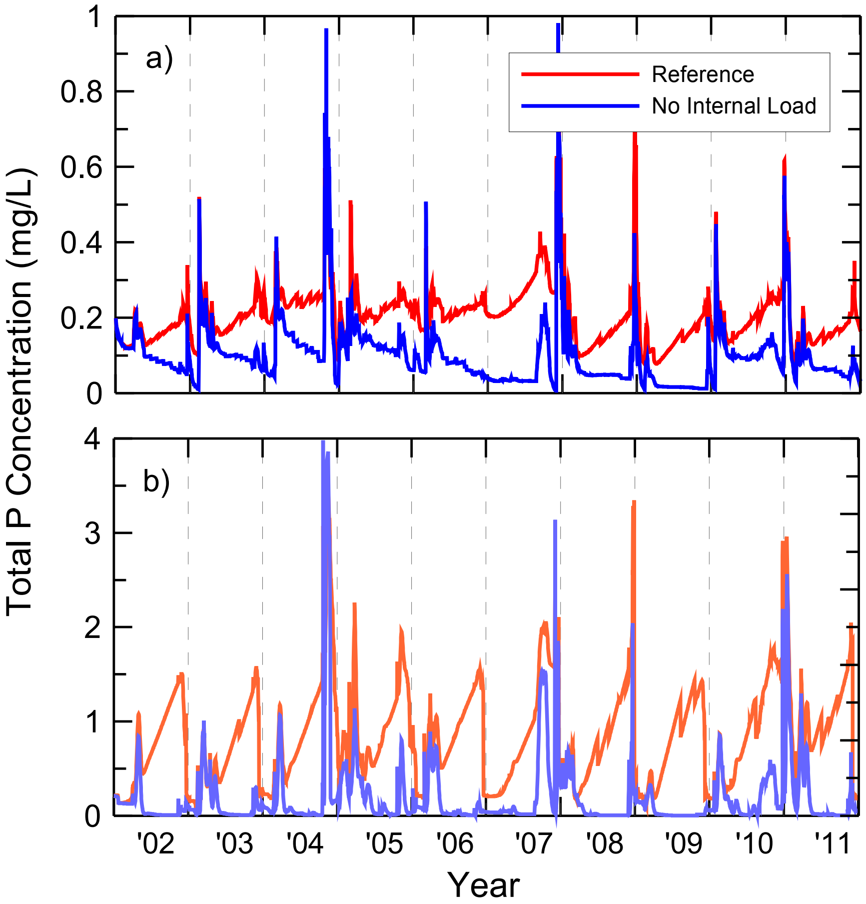

Fig. 10. Predicted total P concentrations comparing the reference scenario with the no-internal loading scenario: a) 1 m below surface and b) 1 m above bottom sediments.

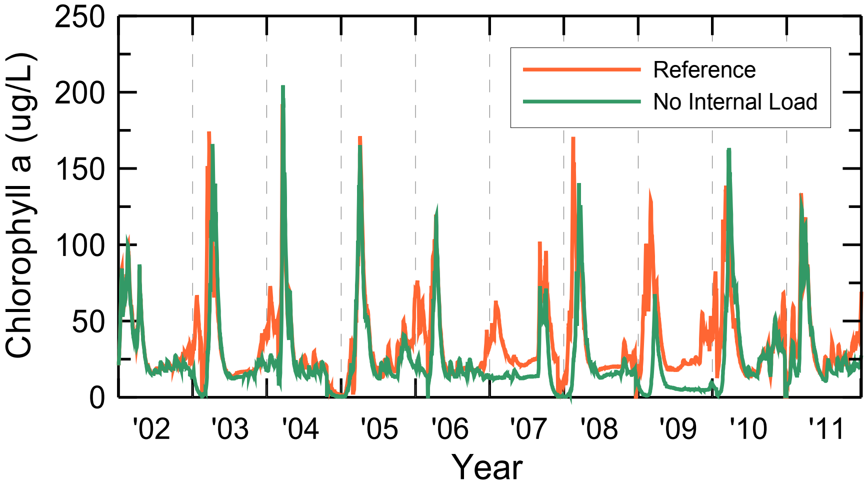

Fig. 11. Predicted chlorophyll a concentrations comparing the reference scenario with the no-internal loading scenario (1 m below surface).

Simulation #3: Hypolimnetic Oxygenation

The previous simulation is thought to represent a theoretical best-case outcome from in-lake restoration through, *e.g.*, use of alum in combination with zeolite sufficient to suppress all release of PO_4-P and NH_4-N. The purpose of this scenario is to evaluate the efficacy of a hypolimnetic oxygenation system for reducing internal loading of nutrients and improving overall water quality in Canyon Lake. Since the previous no internal loading simulation did not explicitly alter DO conditions (beyond those that would be achieved from changes in nutrient availability and productivity), changes in biogeochemical conditions and further transformations could potentially occur as a result of installation and operation of an oxygenation system.

As seen from other simulations (e.g., Anderson, 2007), hypolimnetic oxygenation has negligible effect on the thermal stratification in the lake (Fig. 12a). Conversely, it had a profound effect on the distribution of DO within the water column (Fig. 12b). Oxygen was delivered to the bottom of the lake at a rate of 1,700 lbs O_2 d^{-1} following PACE alternative #10b to offset sediment and water oxygen demands. This oxygen delivery was able to maintain strongly oxic conditions above the sediments, but due to limited vertical exchange, was not fully mixed within the hypolimnion. The model transported oxygen away from the bottom sediments principally by diffusion, and so did not fully capture the features of the hypolimnetic oxygenation system proposed by PACE in which care was taken to mix the DO throughout the hypolimnion (Fig. 12b). Nonetheless, DO concentrations remained above 2 mg L^{-1} even below the thermocline and would thus not meaningfully alter PO_4-P, Fe or related biogochemistry of the lake compared with a uniformly mixed DO condition in the hypolimnion.

Oxygenation did a very good job of suppressing accumulation of N and P above the bottom sediments (Fig. 12c,d), achieving conditions broadly similar to the no internal loading scenario (Fig. 8c,d). One does note slightly higher total N concentrations in the water column however. Total P levels here also show the delivery of nutrients with external loads in late fall-winter of large runoff years (Fig. 12d). Chlorophyll a concentrations also appear at this scale to be broadly similar to those found with no internal loading (Fig. 12e).

A more careful look at predicted concentrations at 1 m below the water surface and 1 m above the bottom sediments better shows the similarities and differences. Total N concentrations in the epilimnion (1 m below water surface) were found to be intermediate between those predicted for the reference scenario and that with no internal loading (Fig. 13a). The average total N concentration over the entire 10-yr simulation period was 1.26 mg L^{-1}, a value that was 10% lower than the reference value (1.40 mg L^{-1}), but 20% higher than the mean value for the no internal loading scenario (1.05 mg L^{-1}) (Table 6). The HOS system more dramatically lowered total N concentrations above the bottom sediments however (1.48 mg L^{-1} vs. 2.65 mg L^{-1} for the reference case), but still greater than the no internal loading scenario (Table 6).

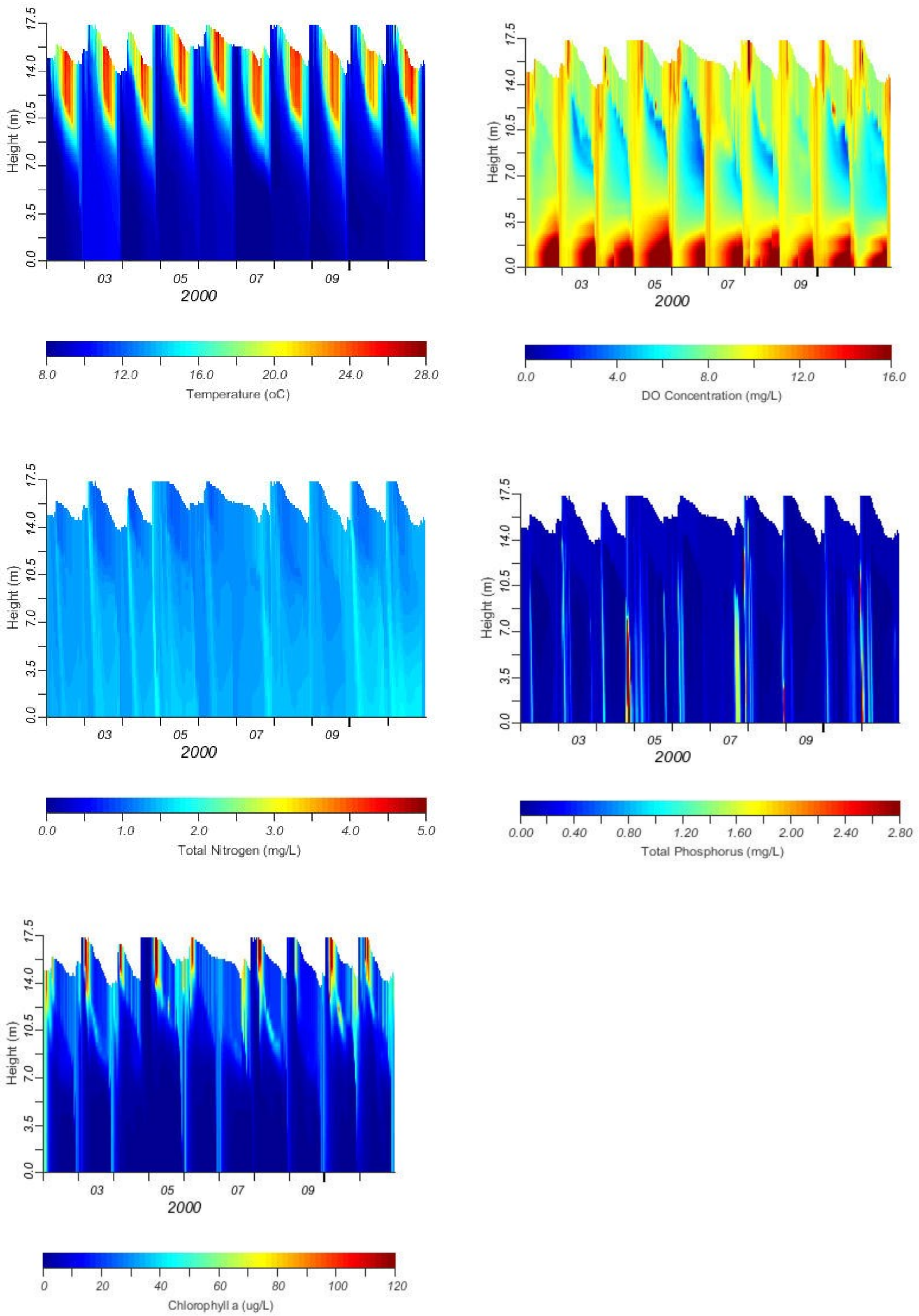

Fig. 12. Predicted water column conditions and water quality in Canyon Lake with hypolimnetic oxygenation: a) temperature, b) DO, c) total N, d) total P and e) chlorophyll a.

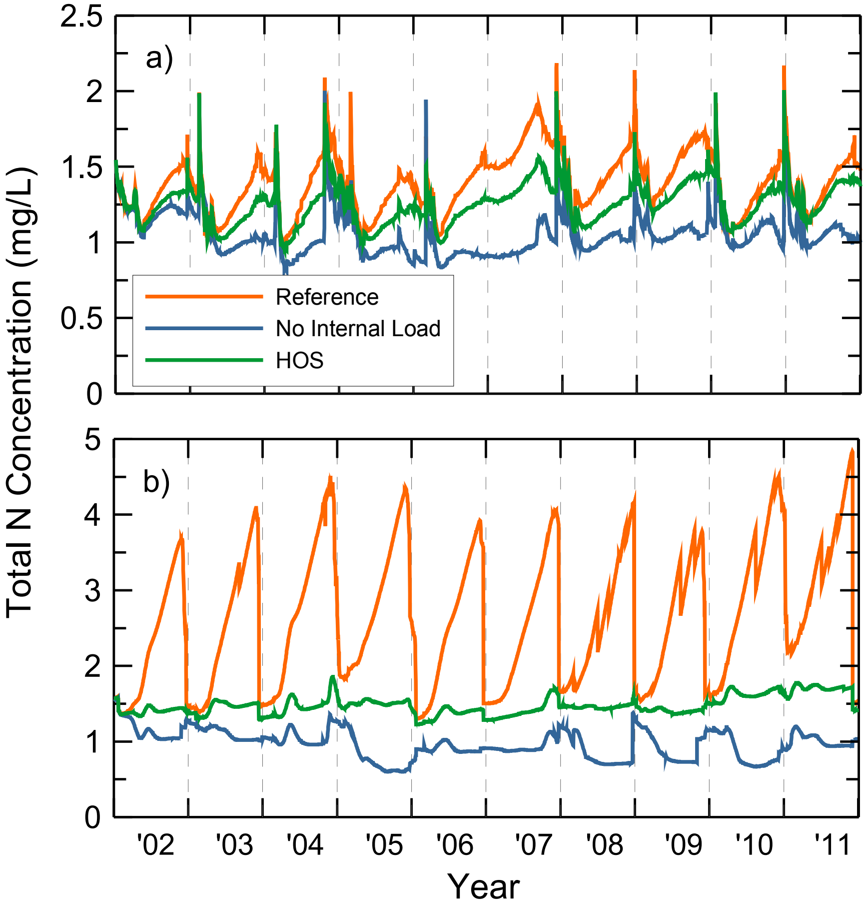

Fig.13. Predicted total N concentrations comparing the 3 scenarios: a) 1 m below surface and b) 1 m above bottom sediments.

The hypolimnetic oxygenation system was predicted to have a greater effect on total P (Fig. 14), achieving levels substantially lower 10-yr mean values than the reference scenario and only modestly larger than the no internal loading scenario (Table 6). The effect of HOS on chlorophyll was limited however (Fig. 15, Table 6). The N-limitation in the lake constrained the improvements in chlorophyll levels that were achieved with HOS despite substantial reductions in total and available P concentrations.

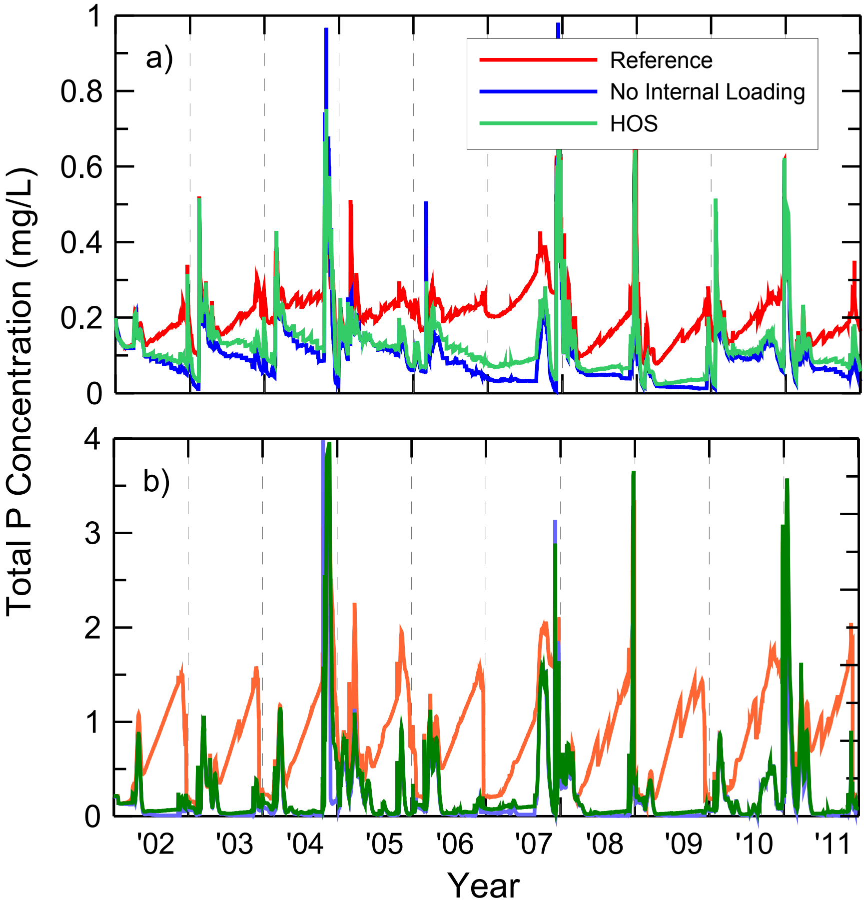

Fig. 14. Predicted total P concentrations comparing the 3 scenarios: a) 1 m below surface and b) 1 m above bottom sediments.

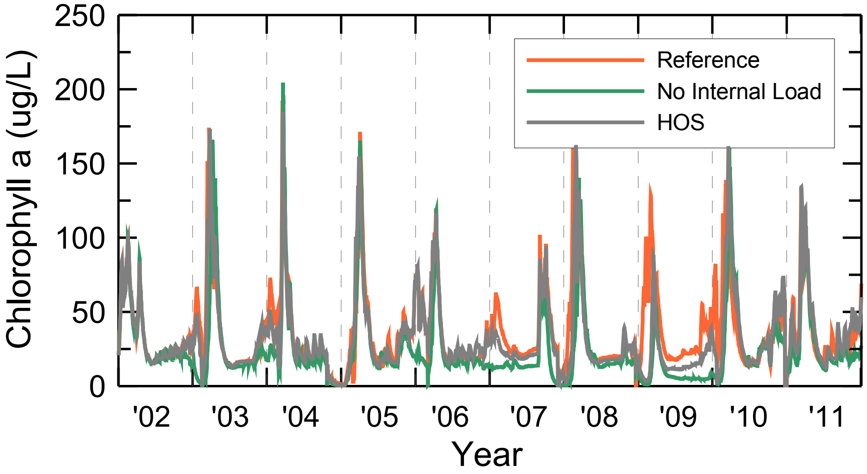

Fig. 15. Predicted chlorophyll a concentrations comparing the reference scenario with the no-internal loading scenario (1 m below surface).

Table 6. Predicted 10-yr average concentrations of total N, total P and chlorophyll a under the reference, no internal loading and HOS scenarios.

Constituent	Depth	Reference Scenario	No Internal Load Scenario	HOS Scenario
Total N	1 m Surface	1.40 ± 0.20	1.05 ± 0.14	1.26 ± 0.14
	1 m Bottom	2.65 ± 0.90	0.97 ± 0.19	1.48 ± 0.12
Total P	1 m Surface	0.21 ± 0.08	0.10 ± 0.09	0.12 ± 0.08
	1 m Bottom	0.85 ± 0.53	0.20 ± 0.46	0.25 ± 0.50
Chlorophyll a	1 m Surface	36.1 ± 27.6	25.5 ± 26.5	33.1 ± 27.0

Conclusions

Results of this study that involved simulation of water quality for the period 2002-2011 demonstrated a number of key findings:

(i) External loading events deliver nutrients to Canyon Lake at rates that can approach or exceed internal loading rates (this occurred 4 out of 10 years in this past 10-yr period of time).

(ii) Canyon Lake is very effective at retaining P and effective at retaining N delivered with runoff, achieving an average of about 84.9% retention of P and 68.2% retention of N based upon these simulations.

(iii) The preferential retention of P relative to N (by about a factor of 2x based upon transported mass) is thought to play a role in the typical P-limitation in Lake Elsinore.

(iv) Elimination of all internal loading to the water column, as would be the theoretical limit from, e.g., application of alum, in combination of zeolite, was found to achieve average reductions of total N in the epilimnion of 25%, total P of 52%, and chlorophyll a of 29% relative to the reference scenario.

(v) Installation and operation of a hypolimnetic oxygenation system achieved a 10% reduction in the average total N concentration, a 43% reduction in total P, and an 8% reduction in chlorophyll a relative to the reference scenario.

(vi) The close connection of Canyon Lake to the San Jacinto River watershed, with regular delivery of often very large external nutrient loads, presents challenges for typical in-lake restoration efforts to fully meet all water quality objectives.

(vii) It appears that control of internal loading will not be sufficient to meet all water quality objectives; in the absence of dramatic reductions in external loading of nutrients, aggressive stripping of nutrients (especially NO_3^-) out of the inflow or water column will also be required.

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Technical Memorandum

Task 3: Evaluation of Alum, Phoslock and Modified Zeolite To Sequester Nutrients in Inflow and Improve Water Quality in Canyon Lake

Objective

The objective of this task was to evaluate the effectiveness of alum, Phoslock and an Al-modified zeolite at sequestering nutrients within inflow and estimate corresponding doses required to meet chlorophyll a target of 25 μg L^{-1} in Canyon Lake.

Approach

The DYRESM-CAEDYM model developed in task 2 was used to predict water quality in Canyon Lake under scenarios that included addition of alum, Phoslock and an Al-modified zeolite (Aqual-P) to inflows. As in task 2, the 10-yr period from 2002-2011 was simulated under both the reference (natural) condition at the lake that included strong thermal stratification and an anaerobic hypolimnion for most of the year, and with installation and operation of the PACE hypolimnetic oxygenation system (HOS). The simulations and associated calculations from task 2 demonstrated the strong linkage between the watershed and external loading of nutrients to the lake, with annual net external loading of nutrients exceeding internal loading 4 years out of 10. The simulations demonstrated that HOS, while effective at significantly reducing internal loading of P and to a lesser extent N, was unable to meet chlorophyll a and nutrient objectives in the lake owing to the annual and often very large loads of nutrients delivered from the watershed. Results from task 2 indicate that stripping of nutrients out of the inflows to Canyon Lake would also be needed to meet all TMDL water quality targets.

Numerical simulations were performed in which PO_4-P concentrations in the inflows from the San Jacinto River and Salt Creek were reduced through irreversible adsorption into a particulate inorganic form that was then allowed to settle out of the water column following Stokes Law. Data describing the adsorption of PO_4-P to each of these materials were taken from published studies; sorption data for alum were taken from Pilgrim et al. (2007), Phoslock data were taken from Haghverseresht et al., (2009), and adsorption data for the Al-modified zeolite (Aqual-P) were taken from Gibbs and Ozkundakci (2011).

Results

<u>Sorbent Properties</u>

The capacity of alum, Phoslock and an Al-modified zeolite to bind PO_4-P in water varies significantly, with alum sorbing a greater amount of PO_4-P than Phoslock or Al-zeolite (Aqual-P) at a given equilibrium solution concentration (Fig.1). The amount of

PO_4-P sorbed onto these materials increases with increasing PO_4-P concentration in solution. For example, the concentration sorbed to Phoslock asymptotically approached its maximum value of about 10 mg PO_4-P/g (Haghereseresht et al., 2009) at equilibrium dissolved concentrations somewhat greater than 0.3 mg/L (Fig. 1a). In this case, the available sites for uptake of PO_4-P are rapidly filled, while a much higher number of sites are available with the alum floc. The Al-zeolite has lower affinity for PO_4-P over these concentration ranges than either alum or Phoslock.

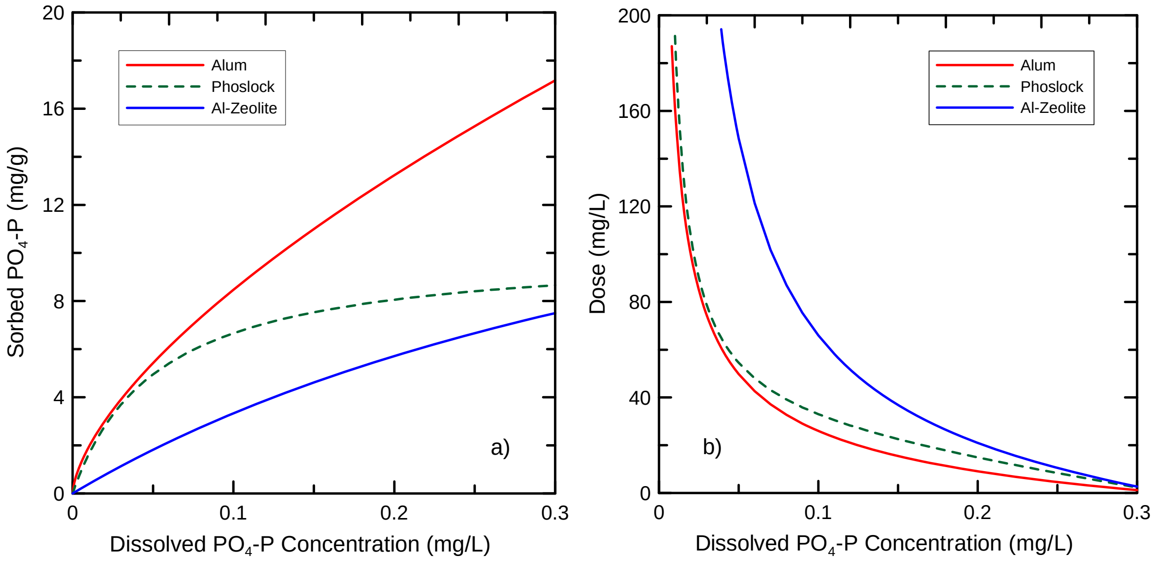

Fig. 1. Comparison of (a) PO_4-P adsorption isotherms and (b) treatment doses and corresponding equilibrium dissolved PO_4-P concentrations for liquid alum, Phoslock and Al-zeolite (Aqual-P).

As a result of the different affinities for PO_4-P, the doses required to achieve a given concentration of PO_4-P in the inflow varied as well (Fig. 1b). All sorbents exhibited a strongly non-linear increase in dose required to achieve lower equilibrium PO_4-P concentrations in solution. Alum required the smallest dose of the three materials to achieve a given equilibrium dissolved PO_4-P concentration, down to about 0.05 mg/L, below which liquid alum and Phoslock were calculated to require similar doses (Fig. 1b). Higher doses would be required to achieve similar dissolved PO_4-P concentrations using the Al-modified zeolite (Fig. 1b).

To reduce the PO_4-P concentration to, e.g., 0.20 mg/L in San Jacinto River inflow (a reduction of 0.12 mg/L from the average dissolved PO_4-P concentration (Anderson, 2012)), doses of 9.1 mg/L alum, 14.9 mg/L Phoslock, or 21.0 mg/L Aqual-P would be required. Higher doses would be needed to reduce PO_4-P in Salt Creek to 0.20 mg/L (a reduction of 0.19 mg/L from the average dissolved PO_4-P concentration in Salt Creek would require 14.4 mg/L alum, 23.6 mg/L Phoslock, or 33.3 mg/L Aqual-P). Greater doses would be needed to remove a larger fraction of the dissolved PO_4-P using any of the materials (*e.g.*, the required alum dose would increase from 9.1 mg/L to 26.0 mg/L to lower dissolved PO_4-P concentrations from 0.20 mg/L to 0.10 mg/L in the San Jacinto River).

Effects on Water Quality

DYRESM-CAEDYM simulations for the 2002-2011 time period were conducted for the (i) reference condition (no in-lake or external treatment), (ii) reduction in dissolved PO_4-P concentration in inflow through addition of alum, Phoslock or Al-zeolite, (iii) operation of the HOS following the PACE 10b design, and (iv) operation of the HOS with inflow treatment/reduction in dissolved PO_4-P. Simulation results for the photic zone (1 m depth) assuming a reduction in external PO_4-P concentrations to 0.10 mg/L are shown in Figs. 3-5. Reduction in PO_4-P concentrations in inflows to 0.10 mg/L predictably lowered the total P concentrations in the lake surface waters by a significant amount as this dissolved PO_4-P was converted to a particulate inorganic form that rapidly settled out of the water column (Fig. 2a).

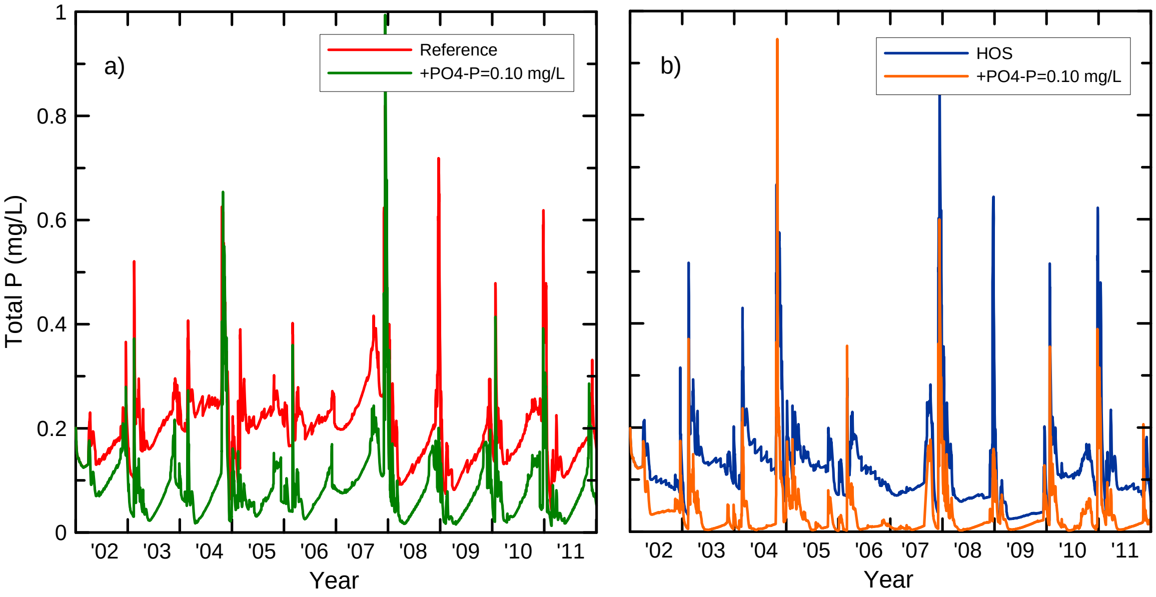

Fig. 2. Predicted total P concentrations for (a) the reference scenario and (b) operation of HOS (with and without treatment that reduced inflow PO_4-P concentration to 0.10 mg/L).

This was achieved without any in-lake treatment, although we do nonetheless see increases in total P during fall mixing and winter runoff events (Fig. 3a). Installation and operation of the HOS was previously shown to have a beneficial effect on total P in the lake (Anderson, 2012), while operation of the HOS in conjunction with treatment that lowered inflow PO_4-P concentration to 0.10 mg/L had the most dramatic effect, with very low total P concentrations (often <0.02 mg/L) present during the summer months (Fig. 2b).

The effects of PO_4-P reductions on total N levels in the epilimnion of the lake were quite modest and, interestingly, tended to increase slightly the predicted total N concentrations relative to both the reference (no HOS) scenario (Fig. 3a) and with operation of the HOS (Fig. 3b). Reductions in PO_4-P concentrations in the inflows to 0.10 mg/L moved the lake into P-limitation, such that less N was taken up by phytoplankton in the lake, less was available to be grazed by zooplankton or settled out of the water column as particulate organic N, and more consequently remained in the water column.

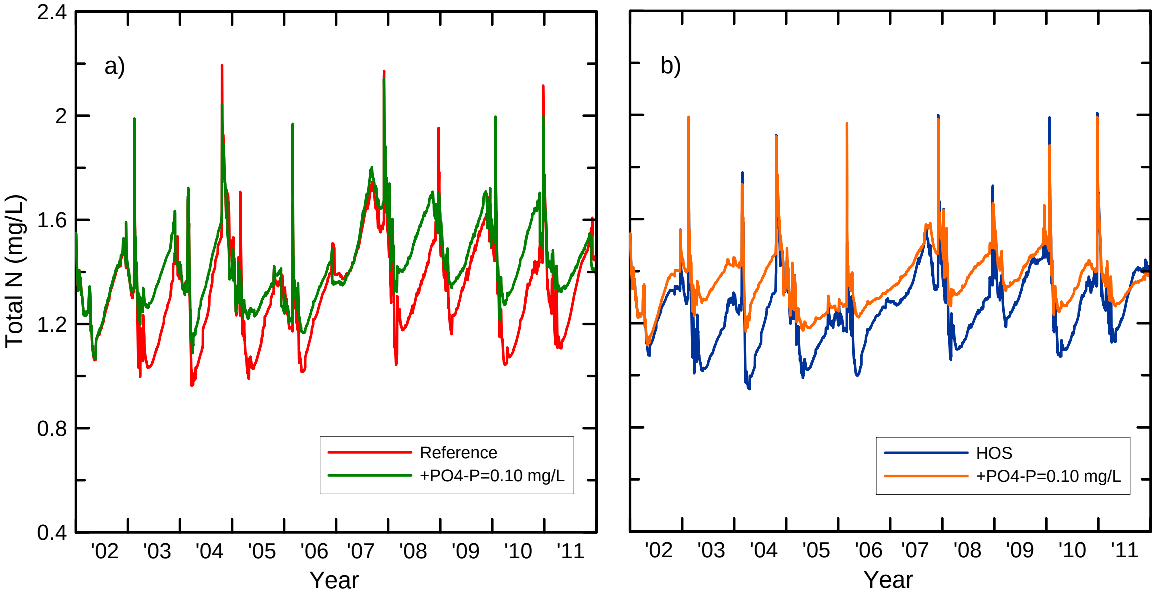

Fig. 3. Predicted total N concentrations for (a) the reference scenario and (b) operation of HOS (with and without treatment that reduced inflow PO_4-P concentration to 0.10 mg/L).

Most importantly, the reduction in PO_4-P concentration to 0.10 mg/L in inflows to the lake also lowered chlorophyll a concentrations (Fig. 4). While reductions in PO_4-P alone (i.e., without HOS or other in-lake treatment) markedly reduced both peak and summer chlorophyll a levels relative to the reference (natural) condition, concentrations nonetheless exceeded 80-100 μg/L late in the year owing to mixing of nutrients generated within the hypolimnion due to internal recycling (Fig. 4a). The combination of reductions in inflow PO_4-P concentrations (via alum, Phoslock or zeolite) and internal nutrient control (via HOS) was predicted to have the greatest beneficial impact on water quality (Fig. 4b). Except for the beginning of 2002, when both externally and internally derived nutrients would have been present, chlorophyll a concentrations were predicted to remain <20 μg/L essentially all of the time, and routinely <14 μg/L. While some uncertainty in these model predictions exists, simulations indicate that potentially quite dramatic improvements in water quality will likely result from the combination of HOS and PO_4-P stripping from inflows.

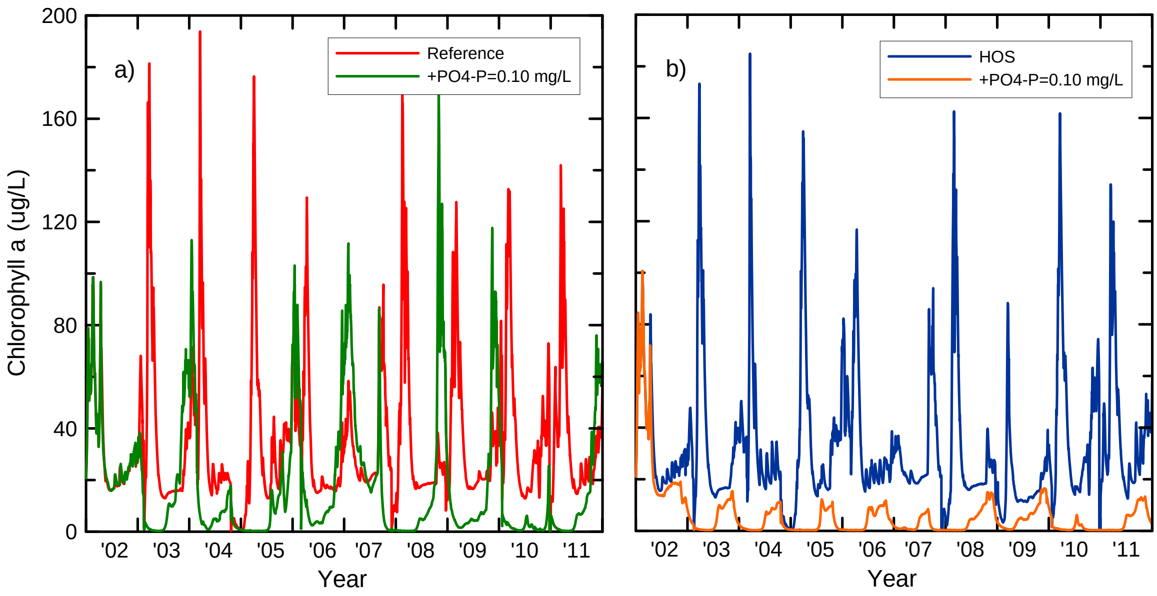

Fig. 4. Predicted chlorophyll a concentrations for (a) the reference scenario and (b) operation of HOS (with and without treatment that reduced inflow PO_4-P concentration to 0.10 mg/L).

A series of additional simulations predicted water quality for several inflow PO_4-P concentrations that would result from different inflow treatments, and results from simulations like those shown in Figs. 3-5 were averaged to yield the 10-yr mean total P, total N, chlorophyll a and hypolimnetic DO concentrations. Simulations thus allow comparison of both internal and external PO_4-P load reductions.

Reductions in inflow PO_4-P concentrations lowered the average total P concentration in the lake epilimnion assuming no in-lake treatment (i.e., no HOS) from more than 0.2 mg/L to about 0.08 mg/L with very low (0.01 mg/L) influent PO_4-P concentrations (Fig. 5a). Lowering the influent PO_4-P concentration to <0.16 mg/L was in fact predicted to lower the decadal average total P concentration in the epilimnion to levels below that prescribed in the TMDL, although this concentration does not reflect the accumulation within the hypolimnion (Fig. 6a).

Installation and operation of the HOS lowered the lake total P concentration by about 40% relative to the reference condition (with no external load treatment), and was predicted to require only a modest reduction in PO_4-P concentration in inflows for the average total P concentration in Canyon Lake to come in under the TMDL target of 0.1 mg/L (Fig. 5a). Reductions in PO_4-P concentrations in inflows below 0.2 mg/L provided comparatively little further improvements in lake total P levels however, indicating that particulate-P inputs from the watershed and remaining internal recycling of PO_4-P are regulating total P levels in the lake.

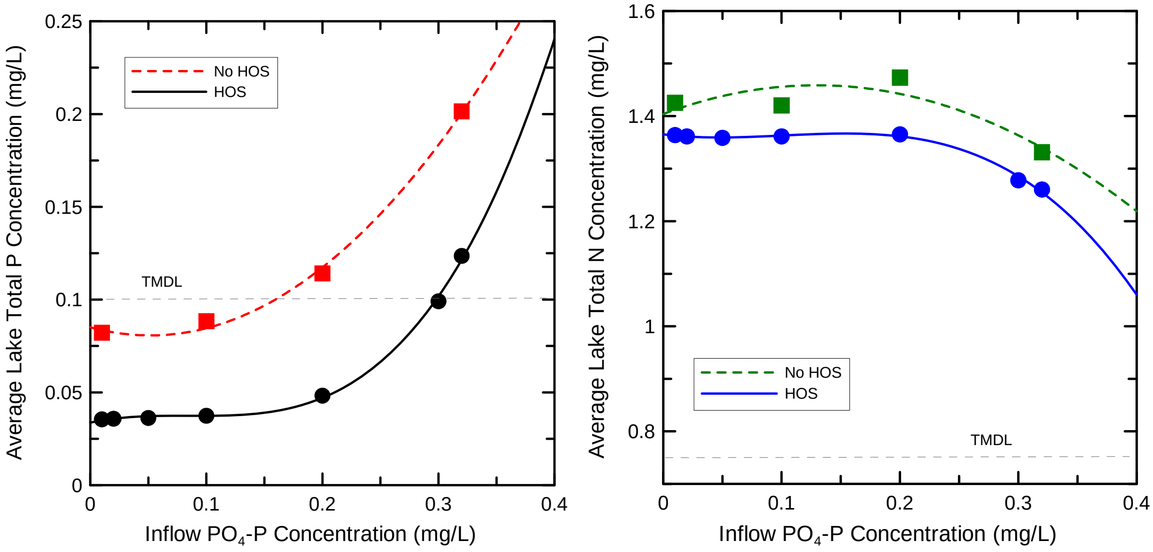

Fig. 5. Predicted average lake concentrations of (a) total P and (b) total N as a function of inflow PO_4-P concentrations.

Reductions in inflow PO_4-P concentrations were found to increase slightly (as shown in Fig. 3b) the average total N concentration in the upper part of the water column (e.g., reduction from 0.32 to 0.20 mg/L PO_4-P in inflow yielded an *increase* in lake total N from 1.26 to 1.37 mg/L) (Fig. 5b). As previously described, this somewhat paradoxical finding is thought to result from a decrease in algal biomass and reduced settling/loss of particulate organic N from the water column, thus maintaining slightly higher dissolved concentrations contributing to higher overall total N levels in the lake. Irrespective of treatment, total N concentrations in Canyon Lake are predicted to remain well-above the TMDL target of 0.75 mg/L.

The dissolved oxygen concentration above the bottom sediments were not strongly affected by changes in inflow PO_4-P concentrations, with the reference (no HOS) condition yielding a predicted 10-yr average concentration near 2 mg/L, well below the 5 mg/L target (Fig. 6a). Installation and operation of the HOS following the PACE design was predicted to yield quite high concentrations above the sediments, with a slight increase in DO with reduced external loading.

The average chlorophyll a concentration (in the epilimnion) responded favorably to reductions in external loading of PO_4-P, especially in combination with operation of the HOS (Fig. 6b). Simulation results indicate that a reduction in inflow PO_4-P concentrations to <0.28 mg/L with HOS or <0.19 mg/L under current conditions (in both San Jacinto River and Salt Creek) would yield a 10-yr average concentration (over the 2002-2011 time period) at or below the 25 μg/L chlorophyll a target (Fig. 6b). Greater reductions in inflow PO_4-P concentrations are predicted to yield correspondingly lower average chlorophyll a concentrations.

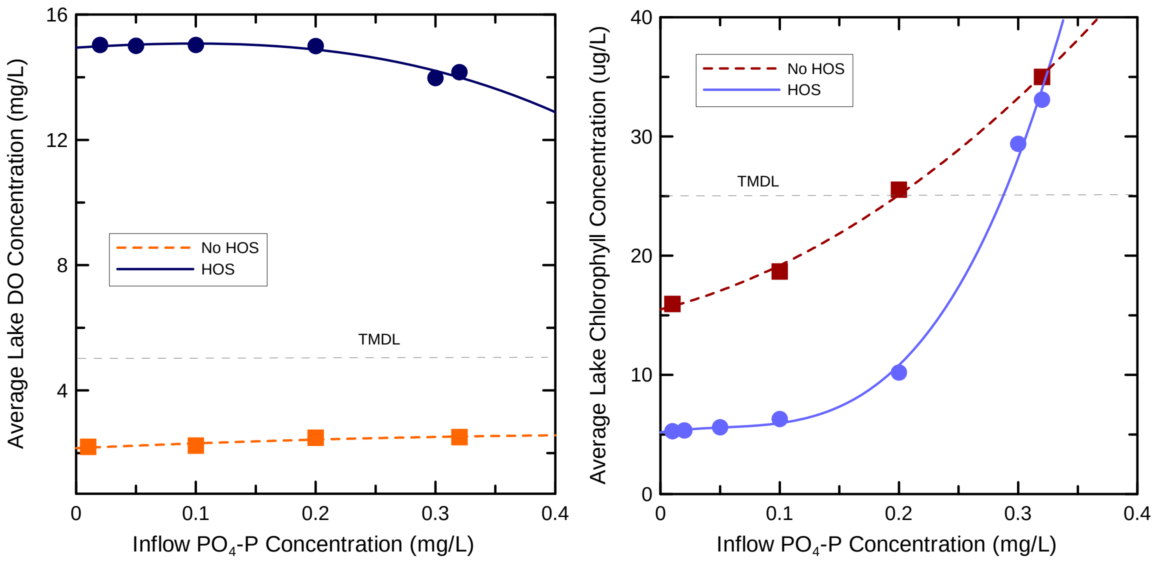

Fig. 6. Predicted average lake concentrations of (a) dissolved oxygen (1 m above bottom) and (b) chlorophyll a as a function of inflow PO_4-P concentrations.

This is a noteworthy result, indicating that reductions in the most bioavailable form of P (PO_4-P) within the runoff, especially when coupled to reductions in internal loading through operation of the HOS, achieve strong reductions in the 10-yr average chlorophyll a concentration in the lake. This combination of actions (installation and operation of the HOS in conjunction with reductions in PO_4-P within inflows to the lake) is thus predicted to meet the total P target (Fig. 5a), DO target (Fig. 6a) and chlorophyll a target (Fig. 6b). This combination of activities was not, however, predicted to approach the total N target of 0.75 mg/L (Fig. 5b), although has clearly shifted the lake to P-limitation (lake TN:TP ratio of about 27 with a reduction in inflow PO_4-P concentration to 0.20 mg/L).

Costs for Treating External PO_4-P Loads

The above modeling analysis was conducted assuming a fraction of PO_4-P was converted to an unreactive particulate inorganic form that would settle out of the water column by gravity. The simulation results shown in Figs. 2-6 are thus not specific to alum, Phoslock or Aqual-P. The amount of sorbent, and thus cost to achieve these reductions, are specific to the material, however. The differences in sorption properties (Fig.1a) were shown to influence the dose required to achieve a given dissolved PO_4-P concentration (Fig. 1b). The modeling suggests that a reduction in PO_4-P concentration to 0.20 mg/L in combination with HOS would achieve marked improvements in water quality and meet TMDL targets for total P, DO and chlorophyll with a significant margin for model uncertainty and error.

The costs for the materials vary (Table 1). The cost of liquid alum was estimated at \$200/ton delivered, or \$0.22/kg alum solution (\$4.95 per kg Al) (Table 1). An approximate cost for Phoslock of \$200 per lb of phosphorus removed was provided by SePro; based upon a claimed P capacity of 20 g P/kg Phoslock, this was converted to material cost of \$8.82 per kg (Table 1). An approximate cost for Aqual-P, the Al-modified zeolite, was requested but has not yet been received.

Table 1. Material costs for inflow treatment.

Material	**Unit Cost**
Alum	\$0.22/kg
Phoslock	\$8.82/kg
Aqual-P	NA

As previously considered in greater detail in the task 2 technical memo (Anderson, 2012), hydraulic loading and total P and total N loading to Canyon Lake has varied markedly over the past decade (Table 2).

Table 2. Total flows and nutrient loads from San Jacinto River and Salt Creek: 2002-2011.

Water Year	**Total Flow In (af)**	**Total P Load (kg)**	**Total N Load (kg)**
2002	1,039	965	2,635
2003	12,345	11,520	33,277
2004	3,107	2,835	8,470
2005	48,264	44,887	129,402
2006	3,347	2,933	9,002
2007	1,783	1,857	5,367
2008	7,359	5,616	17,028
2009	4,981	4,409	13,339
2010	12,688	11,462	33,982
2011	16,435	14,366	43,280

The annual quantity of materials and associated costs needed to achieve a reduction to 0.20 mg/L PO_4-P in San Jacinto River and Salt Creek inflows vary for the 3 materials and over time (due to different annual flows) (Table 3). Relatively modest amounts of alum would be needed (subject to considerations discussed below) for years with low hydraulic loading to the lake (e.g., 23,129 kg or 23.1 metric tons of liquid alum estimated for 2002), although very large quantities would be needed during years with extreme runoff volumes (e.g., 2005). Greater quantities of Phoslock and Aqual-P would be needed owing to the lower binding efficiency for PO_4-P for these materials (Fig. 1a).

Table 3. Predicted annual application mass and material costs: 2002-2011 (0.20 mg/L PO_4-P).

	Mass (kg)			Cost ($)		
Year	**Alum**	**Phoslock**	**Aqual-P**	**Alum**	**Phoslock**	**Aqual-P**
2002	23,129	36,106	53,377	$5,088	$318,451	na
2003	148,415	218,197	342,551	$32,651	$1,924,498	na
2004	146,466	217,849	349,443	$32,222	$1,921,431	na
2005	492,807	724,321	1,137,446	$108,417	$6,388,514	na
2006	41,841	55,743	96,585	$9,205	$491,649	na
2007	65,072	95,651	150,193	$14,316	$843,643	na
2008	89,332	119,254	206,215	$19,653	$1,051,822	na
2009	33,507	43,494	77,348	$7,371	$383,617	na
2010	329,352	457,573	772,965	$72,457	$4,035,793	na
2011	55,320	71,684	127,711	$12,170	$632,251	na

While the quantities of material needed vary within a factor of 3 or so, costs vary between materials by 2 orders of magnitude due to the very large cost differential between alum and Phoslock (Table 1) (as noted above, costs for Aqual-P have not been received, although material costs are likely to be at least broadly similar to Phoslock). Based upon this analysis, Phoslock does not appear to be an appropriate material for treating inflows such as this. Annual material costs for treating inflows with alum to a PO_4-P concentration of 0.20 mg/L ranged from an estimated low of $5,088 in 2002 to $108,417 in 2005. Total alum costs over the 2002-2011 time period, assuming the entirety of all San Jacinto River and Salt Creek flows were treated to 0.20 mg/L PO_4-P, are projected to have been $313,553 (subject to considerations discussed in the next section).

Annual treatment costs vary with dose; the annual average and median costs for the 2002-2011 time period for treatment of inflows with alum to different dissolved PO_4-P concentrations are illustrated in Fig. 7a. The large treatment in 2005 significantly shifted the average annual cost up relative to the median value for the 2002-2011 time period. Treatment with a lower dose of alum, yielding a higher PO_4-P influent concentration to Canyon Lake and correspondingly higher total P and chlorophyll a concentrations there (Figs. 5a and 6b), would decrease costs. This can also be seen in Fig. 7b, where the annual cost of alum based upon the 2002-2011 time period is plotted against the average chlorophyll a concentration. The TMDL chlorophyll a target is included for reference. The alum cost to achieve a given average chlorophyll a concentration varies depending upon operation of the HOS and the cost metric (median or average annual cost for the past 10 yrs) (Fig. 7b).

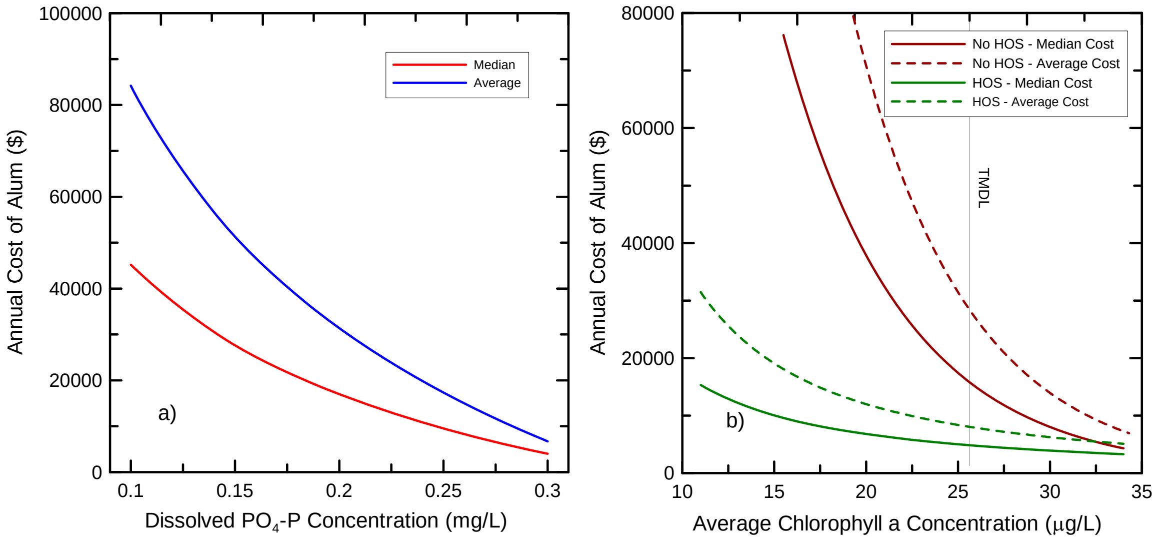

Fig. 7. Projected annual alum costs: a) average and median costs as a function of dissolved PO_4*-P concentration in inflow to Canyon Lake, and b) median and average costs as a function of chlorophyll a concentration with and without operation of HOS.*

Considerations for Treatment with Alum

Alum (aluminum sulfate) dissociates when added to water and dissolved Al undergoes a series hydrolysis reactions that result in the generation of acidity, decrease in pH, and the formation of an aluminum hydroxide ($Al(OH)_3$) floc with a high capacity for sorption of PO_4-P and/or formation of Al hydroxy-phosphates (Fig. 1a). The solubility of the $Al(OH)_3$ floc varies with pH, however, with minimum solubility near circumneutral pH (6-8) and markedly increased solubility at pH values above and below this range. Naturally occurring organic acid ligands derived from soil organic matter, leaf litter and other sources can also bind with Al and thus compete with sorption sites for PO_4-P, as well as inhibit formation of the floc. Dissolved Si can also potentially compete with PO_4-P and form aluminosilicates that would lower the capacity of the added alum to bind PO_4-P. The dose calculations above assume that favorable conditions will allow efficient formation of floc and binding of PO_4-P. Jar tests would be needed to confirm the removal efficiency at the doses proposed and verify low dissolved Al^{3+} concentrations present in treated San Jacinto River and Salt Creek inflow waters. Notwithstanding, Pilgrim et al. (2007) found that low doses of liquid alum (22 mg/L, about 2x that proposed here) reduced PO_4-P concentrations by 66-88% in jar tests conducted with runoff samples.

Ammonium Removal with Al-Modified Zeolite (Aqual-P)

Unlike alum or Phoslock, with which NH_4^+ has minimal interaction, the Al-modified zeolite (Aqual-P) potentially has a high affinity and retention capacity for NH_4^+. Published literature on the NH_4^+ retention of Aqual-P was not found, although Nguyen and Tanner (1998) previously reported on NH_4^+ removal from wastewaters using natural

New Zealand zeolites. Zeolites are naturally occurring minerals with relatively narrow pores through which NH_4^+ can diffuse and adsorb, and which larger, more strongly hydrated cations (such as Ca^{2+}, Mg^{2+} and Na^+) can not access. As a result, zeolites are well-known for their unique selectivity for NH_4^+.

Although costs were not available for this material, it is expected that they would be broadly similar to Phoslock and much higher than liquid alum (Table 1), and would thus not be competitive with alum for inflow treatment of PO_4-P. The unique capacity for this material to retain both PO_4-P and NH_4^+ could iincrease cost-effectiveness for improving overall water quality in Canyon Lake however. To understand the potential additional benefit, the NH_4^+ sorption properties of zeolites were considered further. Nguyen and Tanner (1998) performed laboratory sorption experiments with clinoptilolite and mordenite and developed sorption isotherms (similar to those shown in Fig. 1a for PO_4-P). While a high capacity for adsorption of NH_4^+ was demonstrated (6-8 mg NH_4-N/g zeolite), very high solution concentrations were required to reach these levels (>200 mg/L) (Nguyen and Tanner, 1998). Adsorption could be described by the Langmuir equation, which relates adsorbed concentration (q, in mg/g) to solution concentration (C, in mg/L):

$$q = \frac{Q_{\max} K_{ads} C}{1 + K_{ads} C} \qquad (1)$$

where Q_{max} is the sorption maximum (mg/g) and K_{ads} is an energy term that defines the shape of the isotherm. Nguyen and Tanner (1998) reported Q_{max} and K_{ads} values of 5.7 mg NH_4-N/g and 0.02 L/mg for clinoptilolite, and 8.2 mg NH_4-N/g and 0.034 for mordenite, respectively. We can thus calculate the concentration of NH_4-N adsorbed on these zeolites in San Jacinto River or Salt Creek water by substituting the average NH_4-N concentrations (0.24 and 0.30 mg/L) using these Langmuir parameters; doing so yields 0.027 and 0.034 mg NH_4-N/g clinoptilolite (and 0.066 and 0.083 mg NH_4-N/g mordenite). Thus we see that very little retention of NH_4-N would be expected at the low concentrations of NH_4-N present in these inflows and at zeolite doses of about 30 mg/L (removing only about 1% of the NH_4-N and 0.3% of total inorganic N in the inflows). Based upon this, the capacity for Al-modified zeolite to also bind NH_4-N is not sufficient to offset expected low PO_4-P retention and high relative costs.

Conclusions

Results of these simulations indicate:

(i) Reductions in influent PO_4-P concentrations entering Canyon Lake from the San Jacinto River and Salt Creek can be achieved via addition of alum, Phoslock or Al-modified zeolite.

(ii) Reductions in this readily bioavailable form of P can switch the lake to P-limitation and significantly lower chlorophyll a and total P concentrations in the lake.

(iii) Inflow treatment in conjunction with operation of the HOS was found to be more effective than inflow treatment alone at reducing lake total P and chlorophyll a concentrations, and operation of the HOS was necessary to meet the DO target specified for the lake.

(iv) Alum was found to be much more cost-effective than Phoslock at removing PO_4-P in runoff, and is also expected to be much more cost-effective than Aqual-P (although no cost estimates were available at the time of this report).

(v) The median annual alum cost for 2002-2011, assuming treatment of inflow to a PO_4-P concentration of 0.20 mg/L, was estimated at $16,985/yr, with annual costs that ranged from $5,088 - $108,417 due to variations in annual hydraulic loading from the watershed.

(vi) Jar tests are recommended to confirm dose requirements, Al solubility and PO_4-P removal efficiencies, while algal bioassays are suggested to verify conversion to P-limitation and suppression of algal production.

References

Anderson, M.A. 2012. Evaluation of Long-Term Reduction of Phosphorus Loads from Internal Recycling as a Result of Hypolimnetic Oxygenation in Canyon Lake. Draft Technical Memorandum to LESJWA. 21 pp.

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Technical Memorandum

Task 4a: Evaluate Water Quality in Canyon Lake Under Pre-Development Conditions and TMDL-Prescribed External Load Reductions

Objective

The objective of this sub-task was to evaluate water quality conditions in Canyon Lake assuming no development in the watershed (i.e., under the pre-development scenario) and assuming external load reductions of 73% for total phosphorus and 31% for total nitrogen as prescribed in the TMDL (SARWQB, 2004).

Approach

The DYRESM-CAEDYM model developed and used in tasks 2 (Anderson, 2012a) and 3 (Anderson, 2012b) was utilized to predict water quality in Canyon Lake assuming (i) no development in the watershed and (ii) reductions of external loading of N and P as prescribed in the TMDL. As in the previous simulations, the 2002-2011 time period was evaluated, with the same meteorological and hydrological conditions, with the only difference being the nutrient concentrations in the San Jacinto River and Salt Creek runoff entering the lake. The pre-development scenario was simulated using the external nutrient loading predicted from the TetraTech watershed model for 2002-2009 (Table 1). Total N and total P loading for the equivalent 2010 and 2011 pre-development condition were extrapolated from the contemporary loading values reduced by the percentage reductions for 2003 owing to the similar hydrologic conditions present at that time.

Table 1. Total N and P loading to Canyon Lake under the 3 simulation scenarios: reference (existing conditions), TMDL-prescribed reductions in external loading, and the pre-development condition.

	Total N (kg)			**Total P (kg)**		
Year	**Ref**	**TMDL**	**Pre-Dev**	**Ref**	**TMDL**	**Pre-Dev**
2002	2,635	1,818	1	965	261	0
2003	33,277	22,961	1,546	11,520	3,110	599
2004	8,470	5,844	152	2,835	765	60
2005	129,402	89,287	35,769	44,887	12,119	13,714
2006	9,002	6,211	296	2,933	792	117
2007	5,367	3,703	0	1,857	501	0
2008	17,028	11,749	130	5,616	1,516	52
2009	13,339	9,204	224	4,409	1,190	89
2010	33,982	23,448	1,087	11,462	3,095	430
2011	43,280	29,863	1,385	14,366	3,879	540

Results

Predicted concentrations from 6 depths were combined with volume-elevation data to generate volume-weighted daily concentrations and annual concentrations of total N, total P, and chlorophyll a in Canyon Lake over the 2002-2011 simulation period (Figs. 1-6).

As shown in earlier simulation results, the total N concentration varied over the course of a year and also varied inter-annually in response to differences in external loading (Fig. 1). Reductions in external loading of N to comply with TMDL-prescribed target reductions (reductions of 31%) were found to reduce the daily volume-weighted total N concentrations present in the lake by about 30-35% in the latter half of the simulation period to about 1 - 1.75 mg/L (Fig. 1). The concentrations remained well above the pre-development condition, however, where volume-weighted total N concentrations were generally an order of magnitude lower (Fig. 1).

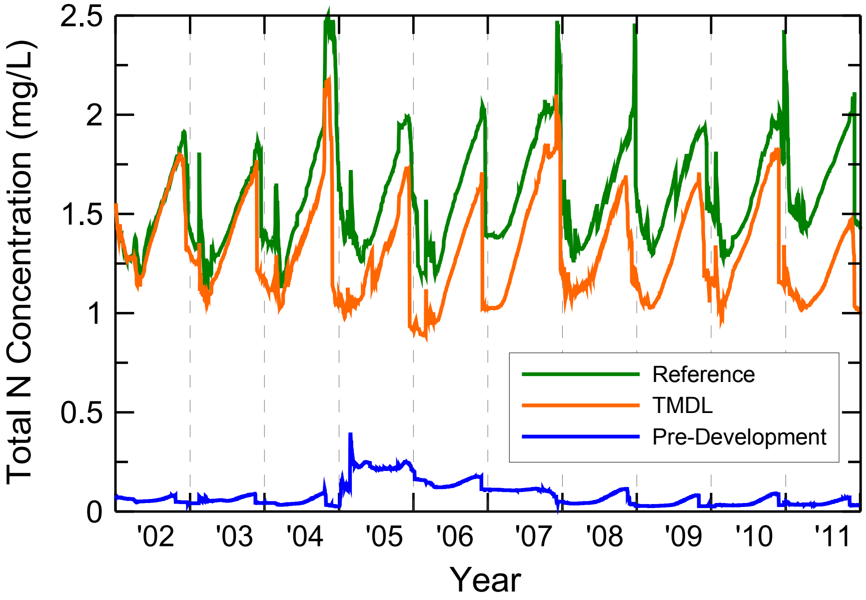

Fig. 1. Volume-weighted daily total N concentrations under the reference (existing) condition, TMDL-prescribed reductions in external loading, and the pre-development scenario.

The daily volume-weighted total N concentrations were then averaged over each calendar year to calculate annual average total N concentrations (Fig. 2). The solid horizontal line represents the 2020 TMDL annual average target of 0.75 mg/L. The annual average total N concentrations varied each year, but generally ranged from about 1.4 - 1.7 mg/L under the reference (existing) conditions, while implementation of BMPs in the watershed to reduce external N loading by 31% lowered the predicted annual average values to approximately 1.2 - 1.4 mg/L (Fig. 2). Thus, although reducing the annual average total N in the water column by a meaningful amount, the values remained above the TMDL target. Predictably, the pre-development (annual average) concentrations were much lower, at all times below the TMDL target by a wide margin (Fig. 2).

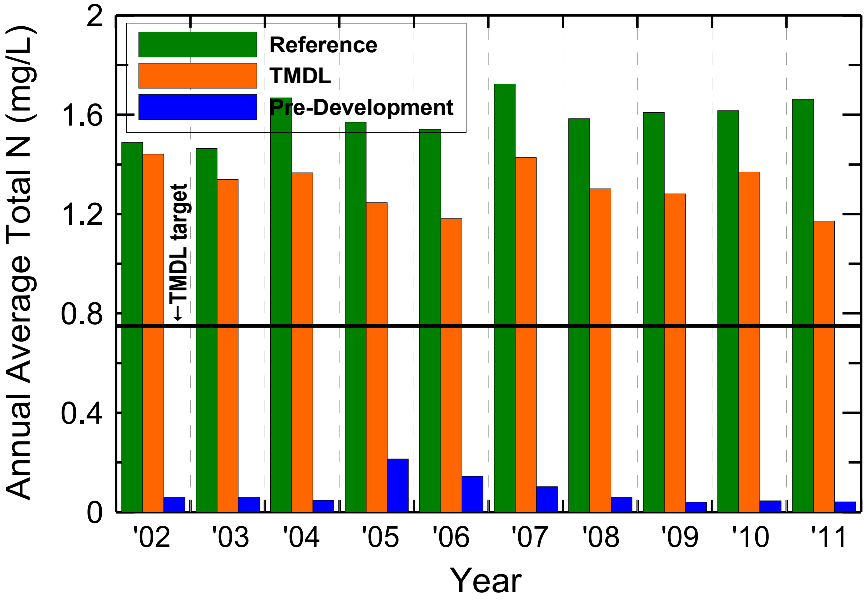

Fig. 2. Annual average total N concentrations under the reference (existing) condition, TMDL-prescribed reductions in external loading, and the pre-development scenario.

The volume-weighted daily total P concentrations in Canyon Lake also exhibited strong seasonal and interannual differences (Fig. 3). Large increases in total P were in fact seen under all 3 scenarios for at least short periods of time and associated with external loading and accumulation to high concentrations within the water column, as well as mixing events that lowered DO and stimulated release from bottom sediments. These events were quite short-lived for the pre-development case, however, as particulate P was rapidly settled out of the water column, resulting in quite low concentrations (<0.05 mg/L) for much of the year (Fig. 3). In contrast, higher volume-weighted total P concentrations (routinely 0.2 - 0.5 mg/L) were present through much of the year under the reference (existing) condition, with volume-weighted concentrations increasing each summer due to release and accumulation of PO_4-P within the (anoxic) hypolimnion. Reduction in external loading by 73% due, e.g., from watershed BMPs, lowered total P levels quite substantially, with concentrations typically 0.1 - 0.4 mg/L.

Reduction in external loading per the TMDL had a marked improvement on annual average total P concentrations relative to the reference (existing) condition (Fig. 4). Depending upon the magnitude of external loading, duration of stratification and other factors, annual average total P concentrations were often reduced by 50% relative to the existing conditions. That a 73% reduction in external loading achieved up to only about a 50% reduction in total P reflects the importance of internal nutrient recycling in Canyon Lake.

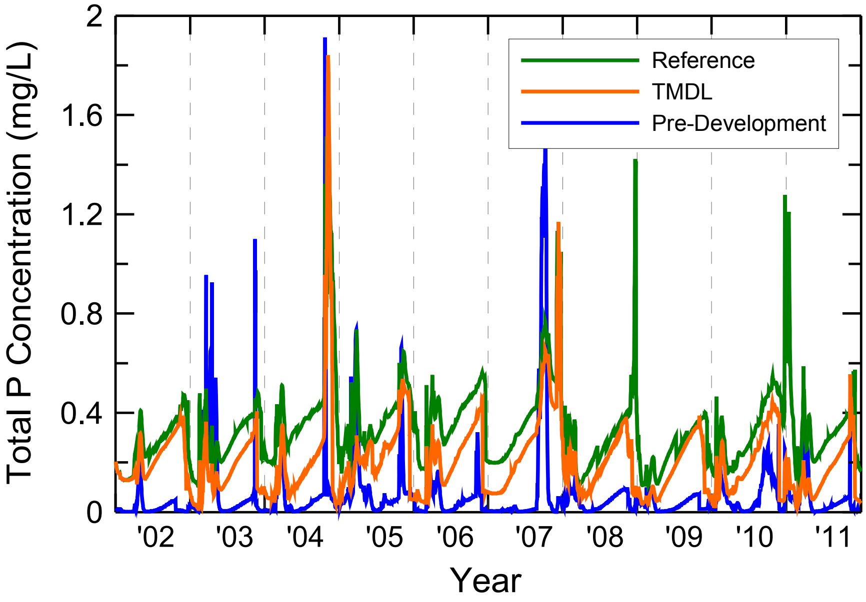

Fig. 3. Volume-weighted daily total P concentrations under the reference (existing) condition, TMDL-prescribed reductions in external loading, and the pre-development scenario.

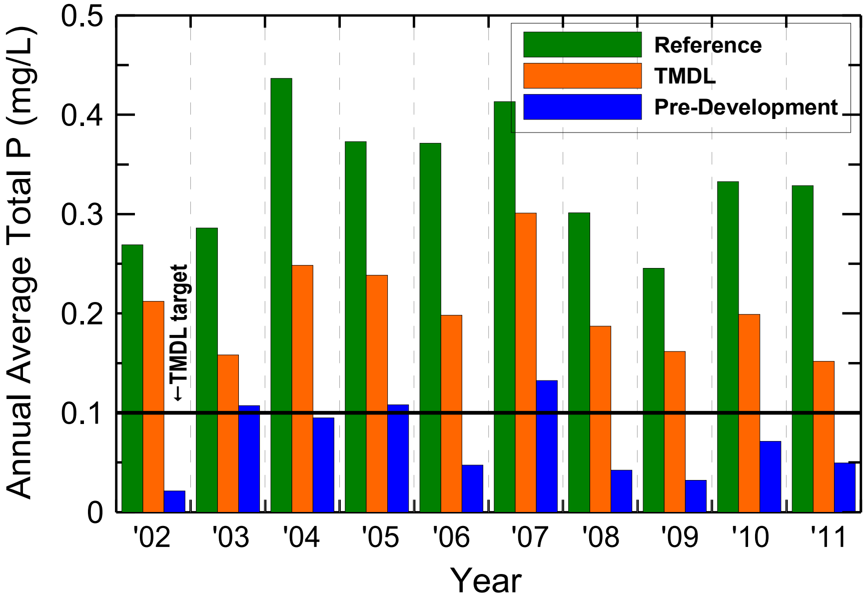

Fig. 4. Annual average total P concentrations under the reference (existing) condition, TMDL-prescribed reductions in external loading, and the pre-development scenario.

Volume-weighted chlorophyll a concentrations exhibited pronounced seasonal variations, with generally much higher concentrations in the fall after mixing and in the spring following external loading events (Fig. 5). Daily volume-weighted concentrations often approached 100 µg/L during these periods under existing conditions, while volume-weighted summer concentrations were more commonly 15-20 µg/L. The process of volume-weighting lowered the chlorophyll levels that one would see within the epilimnion, although this effect was relatively modest since much of the volume of Canyon Lake lies above the thermocline. External load reductions required in the TMDL yielded especially large reductions in chlorophyll levels in the winter and spring, although high concentrations of chlorophyll were generated in the fall, especially following mixing (Fig. 5). Very low concentrations of chlorophyll a were predicted at all times under the pre-development scenario, and only reached 10 µg/L in 2005 following the very large external loading that year (Table 1).

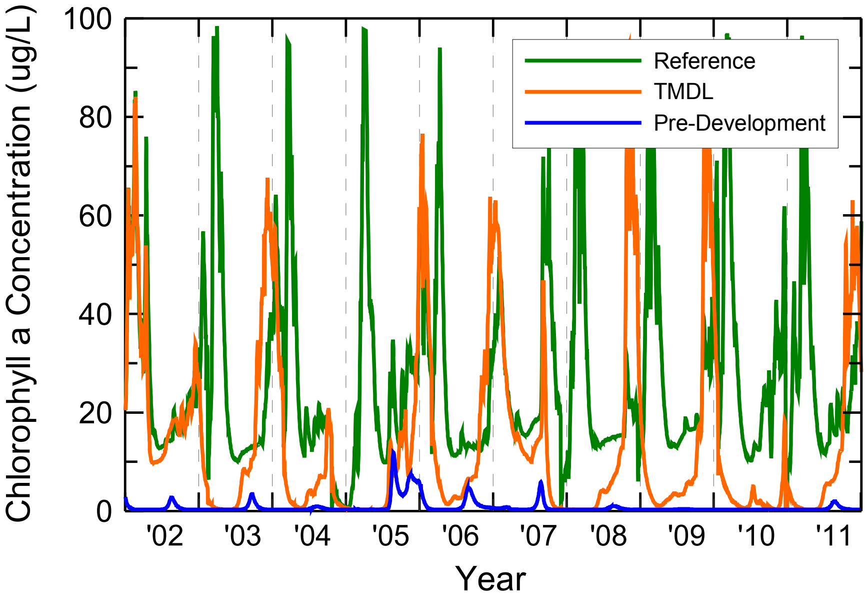

Fig. 5. Volume-weighted daily chlorophyll a concentrations under the reference (existing) condition, TMDL-prescribed reductions in external loading, and the pre-development scenario.

The annual average chlorophyll concentrations calculated from the data in Fig. 5 indicated that Canyon Lake is quite close to compliance with the 25 µg/L TMDL target (Fig. 6). These annual values were calculated from volume-weighted values from the entire water column, as opposed to concentrations reported for the photic zone, as in previous reports, and so are somewhat lower. Irrespective, successful implementation of BMPs to meet the TMDL-prescribed external load reductions is predicted to lower quite dramatically the annual average chlorophyll a concentrations, and should meet the numeric target for chlorophyll a in all but the initial year of the simulation (Fig. 6) (this reflects the lag in water quality, since external load reductions were assumed to be in place beginning only in 2002).

The very low external loading of nutrients in the pre-development scenario (Table 1) was predicted to yield annual average chlorophyll a concentrations of just 1-3 µg/L, with the lingering effect of high external loading in 2005 seen clearly here as well (Fig. 6). This El Nino event was predicted to demonstrably impact water quality for about 3 years.

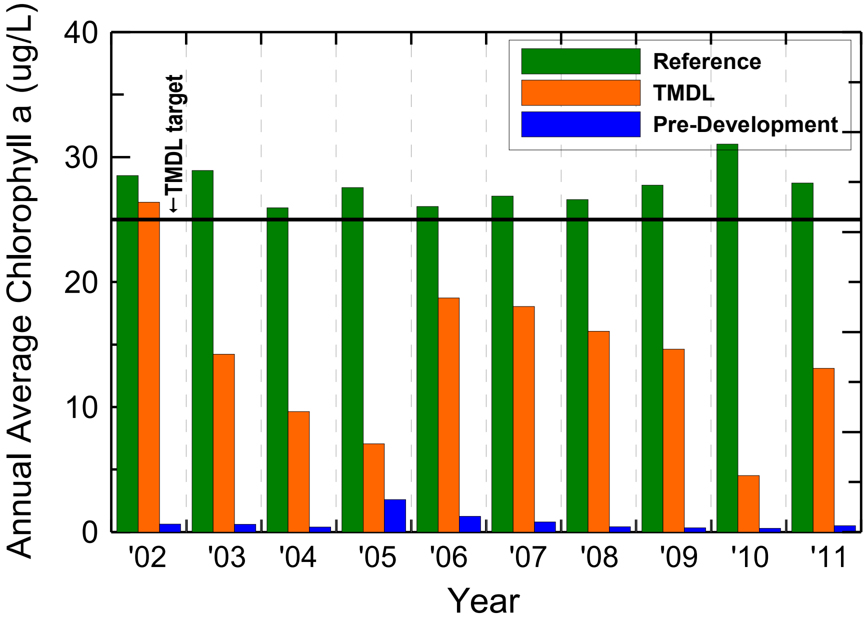

Fig. 6. Annual average chlorophyll a concentrations under the reference (existing) condition, TMDL-prescribed reductions in external loading, and the pre-development scenario.

Unlike nutrient and chlorophyll a concentrations, for which the TMDL specifies maximum annual average values, the DO numerical objective is a minimum daily average value for the hypolimnion (≥ 5 mg/L). Here daily volume-weighted dissolved oxygen (DO) concentrations were calculated for the lowermost 7 m of water column, up to the base of the metalimnion. The volume-weighted hypolimnetic DO concentrations were high during the winter but decreased below 5 mg/L for a considerable period of time each year under all 3 scenarios, including pre-development (Fig. 7). Concentrations were generally somewhat higher under the reference (existing) and TMDL scenarios relative to the pre-development scenario during the winter owing to greater overall productivity in the lake, but DO levels declined more rapidly in the late winter and early spring (Fig. 7). The model predicts a gradient in DO within the hypolimnion, with levels decreasing to almost 0 mg/L immediately above the sediments but several mg/L near the thermocline. Volume-weighting thus reflects more strongly the higher concentrations in the upper hypolimnion where the greatest volume is also found. As a result, the volume-weighted values were generally about 3 mg/L (Fig. 7), while concentrations close to the sediments (as shown in previous reports) were generally very close to 0 mg/L during summer thermal stratification.

The daily volume-weighted hypolimnetic concentrations in Fig. 7 were used to determine the number of days each year the hypolimnetic DO concentrations were below the 5 mg/L TMDL target (Fig. 8). The number of days each year varied from about 260 to 340 for the reference (existing) scenario (average duration of 294 days), while reduction in external loading per the TMDL lowered the number of days each year by approximately 20, to an average duration of 273 days or about 9 months (Fig. 8).

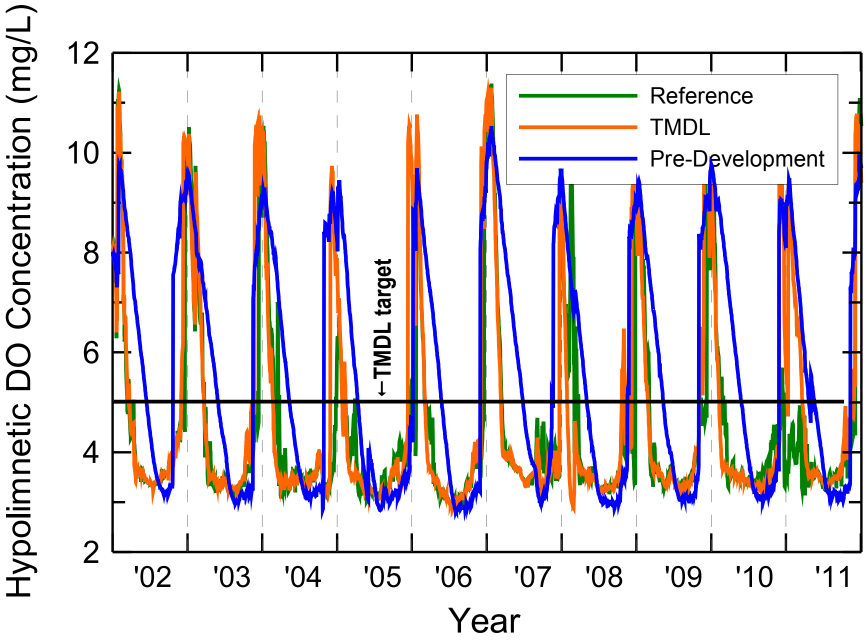

Fig. 7. Volume-weighted daily hypolimnetic DO concentrations under the reference (existing) condition, TMDL-prescribed reductions in external loading, and the pre-development scenario.

Importantly, even the pre-development scenario was predicted to yield hypolimnetic concentrations < 5 mg/L an average of 181 days or 50% of the year (Fig. 8)

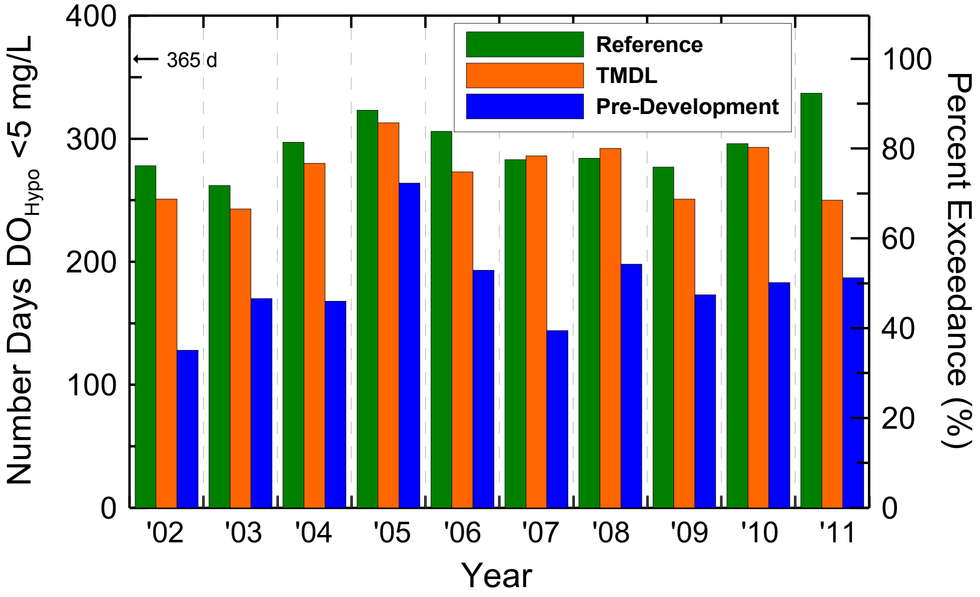

Fig. 8. Number of days each year when hypolimnetic DO concentrations were below the TMDL target of 5 mg/L under the reference (existing) condition, TMDL-prescribed reductions in external loading, and the pre-development scenario.

Conclusions

Results from these simulations indicate:

(i) Reductions in external loading of N by 31% and total P by 73% resulted in moderate reductions in total N concentrations and more substantial reductions in total P concentrations in Canyon Lake, although annual average values remained above TMDL numerical targets.

(ii) TMDL-prescribed external load reductions were predicted to achieve compliance with the 25 μg/L chlorophyll a target for the lake assuming volume-weighting within the entire water column.

(iii) Low concentrations of total P and very low concentrations of total N and chlorophyll a were predicted under the pre-development scenario.

(iv) Daily volume-weighted DO concentrations in the hypolimnion were below the DO TMDL target much of the year for all scenarios, including the pre-development scenario where DO in the hypolimnion was <5 mg/L approximately 50% of the year.

References

Anderson, M.A. 2012a. *Evaluation of Long-Term Reduction of Phosphorus Loads from Internal Recycling as a Result of Hypolimnetic Oxygenation in Canyon Lake.* Draft Technical Memorandum, Task 2, to LESJWA. 21 pp.

Anderson, M.A. 2012b. *Evaluation of Alum, Phoslock and Modified Zeolite to Sequester Nutrients in Inflow and Improve Water Quality in Canyon Lake.* Draft Technical Memorandum, Task 3, to LESJWA. 12 pp.

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Task 5a: Simulations Using Refined Model Parameter Set Under Steady-State Conditions for Lake Elsinore

- A refinement of earlier model predictions made based upon information available at that time and prior to alum treatment for P removal at EVMWD and carp removal program
- Approach same as that used in Anderson (2006) that calculated a steady-state condition in Lake Elsinore under different management actions
- The average recycled H_2O flow from EVMWD (5660 af yr^{-1}) assumed to be added to lake at TP concentrations of 0.5, 0.4, 0.3, and 0.2 mg L^{-1}
- 75% reduction in carp populations also assumed

$$C = \frac{\dfrac{H(\sum_i Q_i C_i + PRA_w C_w)}{V} + iOC + fP_f M_f B + w_r A_r B}{\nu}$$

where:

C – predicted steady state conc of TP

H – mean depth

Q_i – flow from source i

P – precipitation rate

R – runoff coefficient

A_w – local watershed area

C_w – conc in local runoff

V – volume of lake

i – slope of internal loading function

O – scalar for aeration effects

f – carp resuspension rate

P – carp population

M – average mass of carp

B – bioavailable P in sediment

W_r – wind resuspension rate

A_r – fraction of sediments resuspended

ν – settling velocity

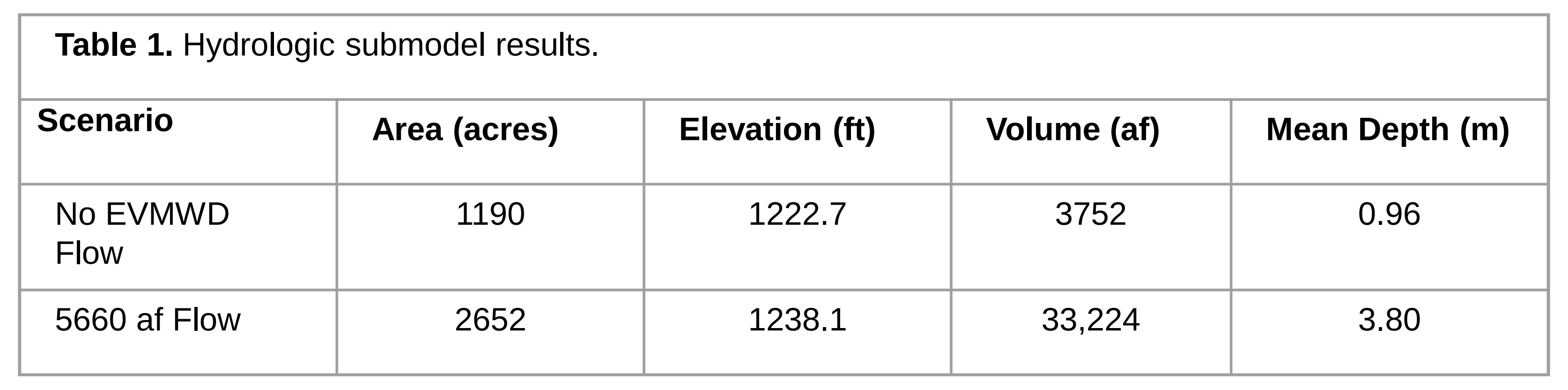


Table 1. Hydrologic submodel results.

Scenario	**Area (acres)**	**Elevation (ft)**	**Volume (af)**	**Mean Depth (m)**
No EVMWD Flow	1190	1222.7	3752	0.96
5660 af Flow	2652	1238.1	33,224	3.80

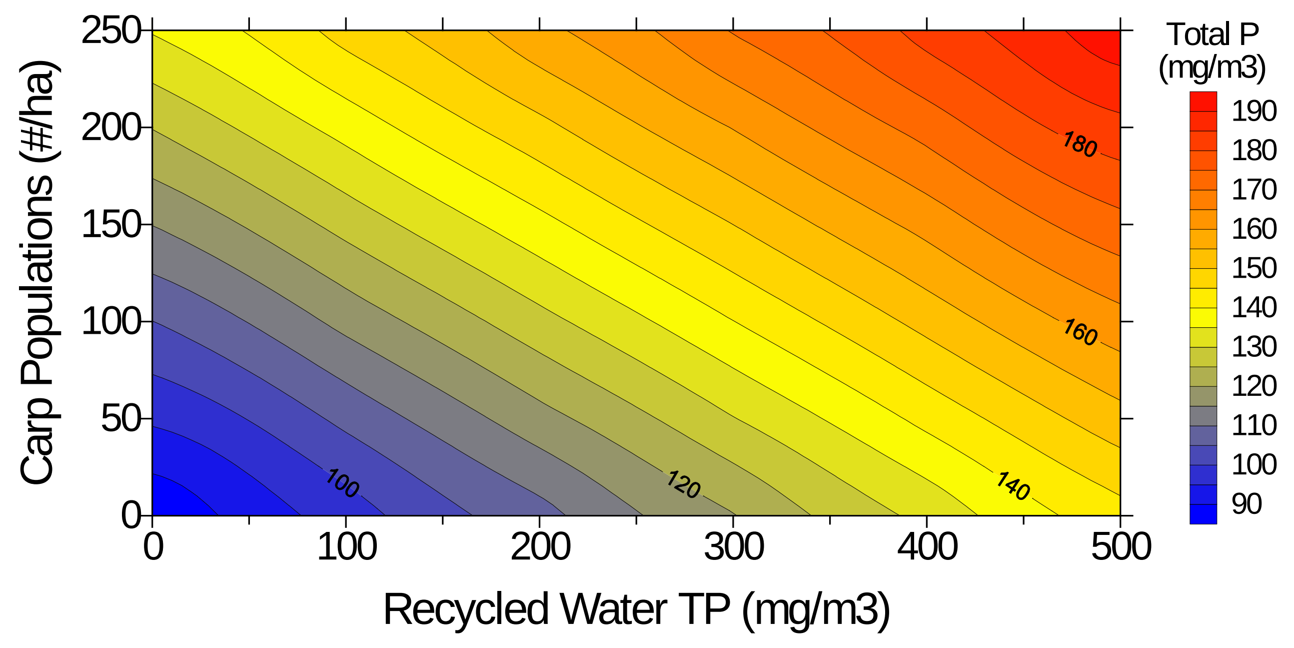
- Assuming the geometric mean annual San Jacinto R. flow to lake (558 af yr^{-1}) persisted for a number of years, a very low lake level and very shallow depth are predicted
- Delivery of 5660 af yr^{-1} from EVMWD results in much higher lake level, 4x greater depth and a 9x greater volume

Table 2. Predicted median water quality and phosphorus loading assuming 0 af yr^{-1} (reference) and 5660 af yr^{-1} EVMWD recycled water input with TP 0.2-0.5 mg L^{-1}, geometric mean San Jacinto River flow to Lake Elsinore (558 af yr^{-1}) at 0.22 mg L^{-1} total P, and 75% reduction in carp population (226 carp ha^{-1}).

Scenario	**Water Quality Variables**			**Phosphorus Loading (mg m^{-2} d^{-1})**				
Influent P Conc	TP mg L^{-1}	Chl a ug L^{-1}	Z_{sd} m	Ext	Internal	Wind	Carp	Total
No flow	0.812	1201	0.05	0.7	67.7	11.0	0.7	80.1
0.5 mg L^{-1}	0.189	145	0.33	1.2	16.0	1.0	0.7	18.9
0.4 mg L^{-1}	0.181	137	0.35	1.1	15.3	1.0	0.7	18.1
0.3 mg L^{-1}	0.165	119	0.38	0.9	14.0	1.0	0.7	16.6
0.2 mg L^{-1}	0.152	107	0.41	0.7	12.9	1.0	0.7	15.3

- Delivery of recycled water predicted to have dramatic effect on water quality as well

- Relatively modest subsequent improvements predicted when total P concentrations further reduced in recycled water
- This results in part because of inputs from other external sources (e.g., local runoff and San Jacinto River), and from wind and carp resuspension



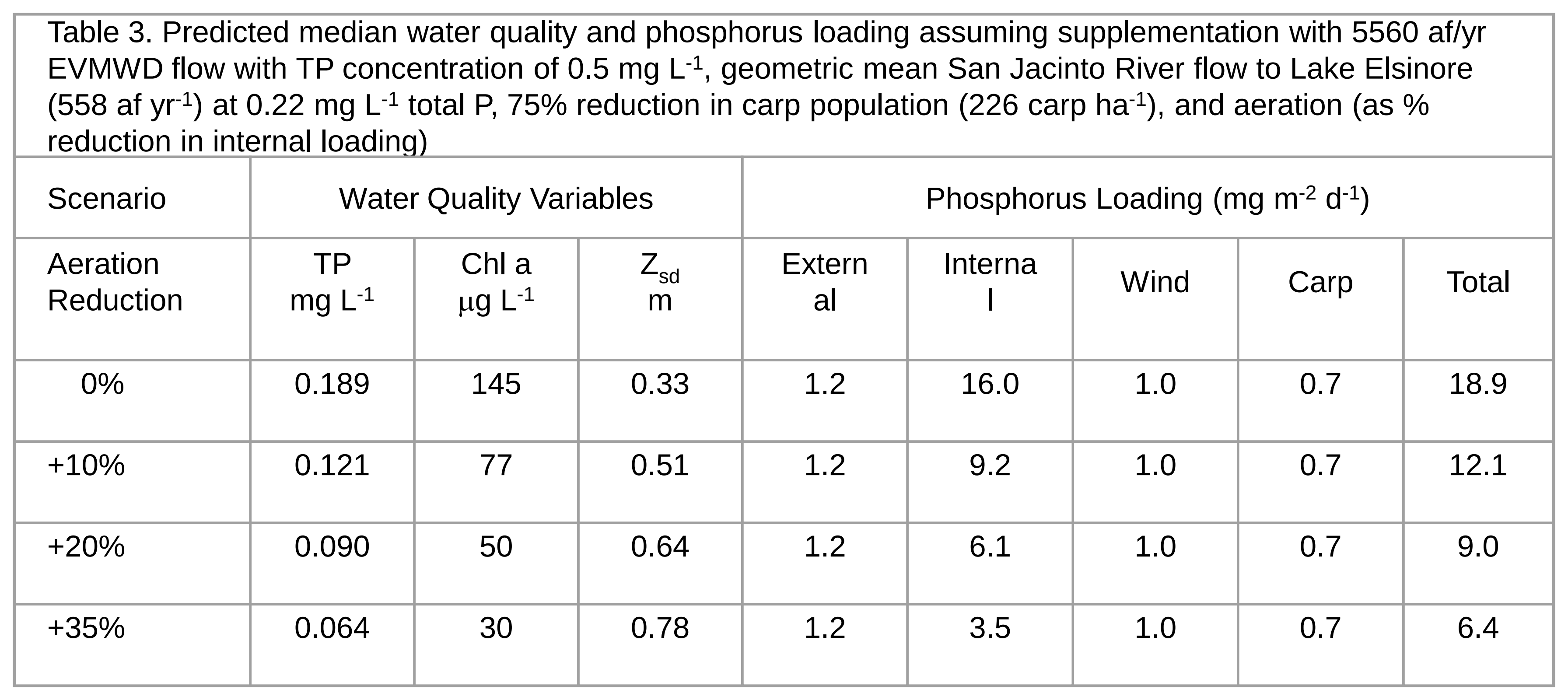


Table 3. Predicted median water quality and phosphorus loading assuming supplementation with 5560 af/yr EVMWD flow with TP concentration of 0.5 mg L^{-1}, geometric mean San Jacinto River flow to Lake Elsinore (558 af yr^{-1}) at 0.22 mg L^{-1} total P, 75% reduction in carp population (226 carp ha^{-1}), and aeration (as % reduction in internal loading)

Scenario	Water Quality Variables			Phosphorus Loading (mg m^{-2} d^{-1})				
Aeration Reduction	TP mg L^{-1}	Chl a µg L^{-1}	Z_{sd} m	External	Internal	Wind	Carp	Total
0%	0.189	145	0.33	1.2	16.0	1.0	0.7	18.9
+10%	0.121	77	0.51	1.2	9.2	1.0	0.7	12.1
+20%	0.090	50	0.64	1.2	6.1	1.0	0.7	9.0
+35%	0.064	30	0.78	1.2	3.5	1.0	0.7	6.4

- Effective aeration predicted to more significantly improve water quality than reductions in TP in recycled H_2O
- Characterization of sediment Fe speciation, color, etc. suggest limited effectiveness of system

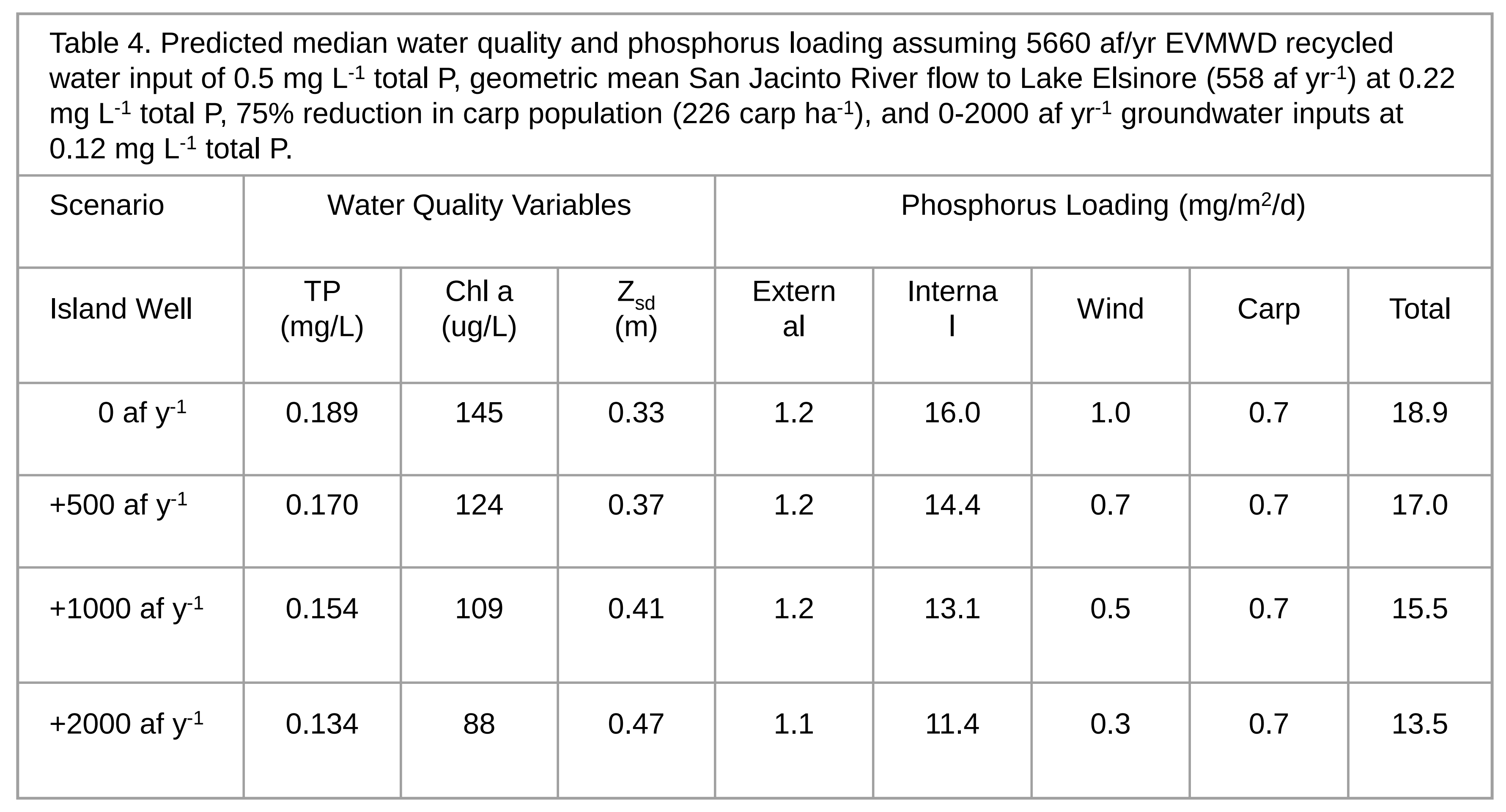


Table 4. Predicted median water quality and phosphorus loading assuming 5660 af/yr EVMWD recycled water input of 0.5 mg L^{-1} total P, geometric mean San Jacinto River flow to Lake Elsinore (558 af yr^{-1}) at 0.22 mg L^{-1} total P, 75% reduction in carp population (226 carp ha^{-1}), and 0-2000 af yr^{-1} groundwater inputs at 0.12 mg L^{-1} total P.

Scenario	Water Quality Variables			Phosphorus Loading (mg/m^2/d)				
Island Well	TP (mg/L)	Chl a (ug/L)	Z_{sd} (m)	External	Internal	Wind	Carp	Total
0 af y^{-1}	0.189	145	0.33	1.2	16.0	1.0	0.7	18.9
+500 af y^{-1}	0.170	124	0.37	1.2	14.4	0.7	0.7	17.0
+1000 af y^{-1}	0.154	109	0.41	1.2	13.1	0.5	0.7	15.5
+2000 af y^{-1}	0.134	88	0.47	1.1	11.4	0.3	0.7	13.5

- Addition of groundwater predicted to raise lake level and further improve water quality through dilution and reduced wind resuspension

- The steady-state approach provides a useful theoretical basis for comparing hydrologic and water quality conditions, although such static conditions will not realistically be met
- Dynamic conditions and hydraulic linkages between watershed, Canyon Lake and Lake Elsinore will be undertaken in tasks 2-4 and 5b
- The model simulations will serve as a more comprehensive assessment and include P, N, DO, and related physical, chemical and ecological conditions in both Lake Elsinore and Canyon Lake

Technical Memorandum

Task 6: Predicted Water Quality in Canyon Lake with In-Lake Alum Treatments and Watershed BMPs

Objective

The objective of this task was to evaluate the predicted water quality in Canyon Lake that would result from implementation of watershed BMPs, in-lake alum treatments, and watershed BMPs in conjunction with alum treatments.

Approach

The DYRESM-CAEDYM model developed in earlier studies was used to assess water quality following in-lake alum treatments and with watershed BMPs. A total of 12 different scenarios were evaluated (Table 1). The existing scenario (“Existing”) represents the model-predicted water quality in Canyon Lake over 2002-2011, while the BMPs scenario represents the predicted water quality that would result from a 15% reduction in total N and total P (assumed here to be a uniform reduction in both dissolved and particulate forms of N and P). This scenario thus differs from that evaluated in Task 4a that considered the TMDL-prescribed reductions of total N of 31% and that for total P of 73% (Anderson, 2012).

Table 1. Summary of the 12 simulations conducted evaluating BMPs, alum treatments, and BMPs in conjunction with alum treatments for Canyon Lake.

Scenario	**BMP**	**PO_4 Stripping**	**Int Load Red**
Existing	-	-	-
BMPs	√	-	-
Alum H	-	√	-
Alum W	-	√	-
Alum H + W	-	√	-
Alum H + IL	-	√	√
Alum H + W + IL	-	√	√
BMP + Alum H	√	√	-
BMP + Alum W	√	√	-
BMP + Alum H+ W	√	√	-
BMP + Alum H + IL	√	√	√
BMP + Alum H + W + IL	√	√	√

The effects of annual alum applications to the lake were also evaluated (with and without implementation of watershed BMPs) (Table 1). Whereas we previously considered microfloc alum injection into the San Jacinto River and Salt Creek to lower bioavailable PO_4-P (Task 3), these scenarios evaluated in-lake treatments. The "Alum H" scenario considered annual additions of alum on October 1 of each year at a dose sufficient to strip the hypolimnion (H) of almost all of the PO_4-P that had accumulated to that point, but assumed it would achieve no reductions in internal loading. Similarly, the "Alum W" scenario considered that which alum was also added annually at a lower effective dose to the entire water column during the winter (W) (potentially 60,000 kg yr^{-1}, on February 1). The winter treatment thus served as an alternative to inflow treatment and would strip much of the PO_4-P that had been delivered to the lake with inflows through the end of January (and remained in the basin, that is, not spilled to Lake Elsinore). The "Alum H + W" scenario considered both of these annual alum additions designed to strip PO_4-P out of the water column. These treatments were assumed to not substantively influence internal loading of PO_4-P from bottom sediments, however.

Larger doses during the hypolimnetic treatment (potentially 140,000 kg yr^{-1}) would be expected to also reduce internal loading rates. The effectiveness of such treatments would be strongly dependent upon external loading events, and such events would potentially yield short-lived benefits. For the purposes of these simulations, such reductions in internal loading ("IL") were assumed to achieve an annual average reduction of 50%. The "Alum H + IL" scenario thus allowed for both hypolimnetic stripping of PO_4-P and a 50% reduction in the annual average internal PO_4-P loading rate. Similarly, the "Alum H + W +IL" scenario involved alum treatment and stripping of PO_4-P out of the water column on February 1 and hypolimnetic treatment on October 1 combined with a 50% reduction in annual average internal loading. The whole water column winter treatment (Alum W) was not assumed to substantively alter internal PO_4-P loading due to the lower dose and lower corresponding Al concentration in the lake (during a time when potentially large external inputs may yet still arrive with storms in February and March). These alum scenarios were also evaluated in combination with the 15% external load reductions achieved through BMPs in the watershed (designated with "BMP) (Table 1).

Results

A large volume of data was generated in these 12 different sets of simulations. Volume-weighted annual average and 10-yr average concentrations were calculated for total P, total N, and DO while surface concentrations for chlorophyll a were determined. Volume-weighted DO concentrations were calculated only for the lowermost 7 m of the water column. Volume-weighted nutrient concentrations are presented to reflect the total inventory of nutrients in the water column of Canyon Lake as was reported in Task 3. Annual average concentrations of total P, total N, chlorophyll a and DO are provided in Figs. 1-4 for (i) the existing condition, (ii) with BMPs implemented in the watershed (15% reductions in nutrient loading), and (iii) with annual alum treatments of the hypolimnion that stripped PO_4-P out of the lower water column and also lowered internal loading rates by 50%. Reduction of external loading of nutrients by 15% through implementation of watershed BMPs lowered annual average total P concentrations in the lake by an average of 0.05 mg/L, while alum treatment of the hypolimnion was predicted to lower volume-weighted concentrations by an average of 0.22 mg/L (Fig. 1). Hypolimnetic alum treatment was predicted to bring volume-weighted annual concentrations below the 0.1 mg/L total P target in 2 of 10 years (Fig. 1).

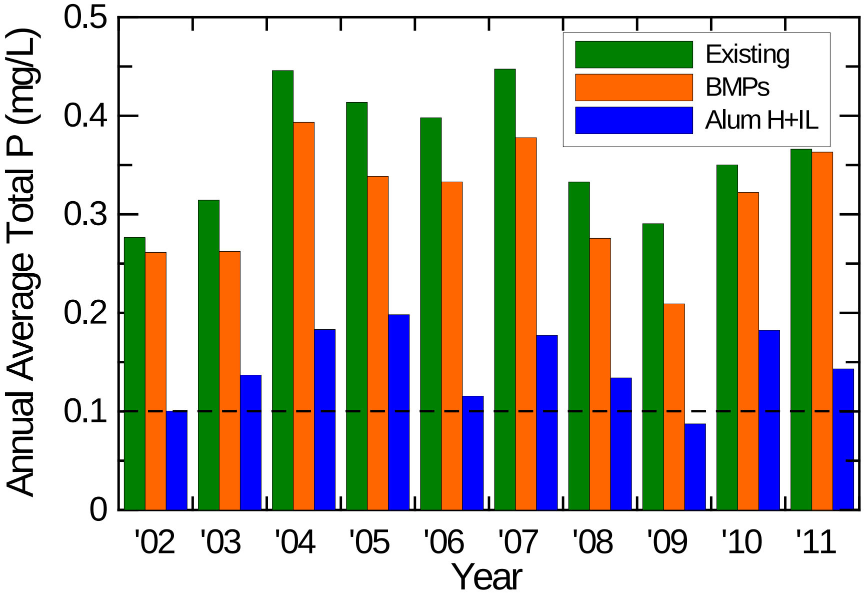


Fig. 1. Volume-weighted annual average total P concentrations in Canyon Lake under (i) model-simulated existing conditions, (ii) with implementation of watershed BMPs achieving 15% external load reductions, and (iii) with alum treatment of hypolimnion with internal PO_4 load reductions.

Total N concentrations were less strongly affected by BMPs or alum treatment (Fig. 2), with BMPs and hypolimnetic alum treatment with internal P load reductions predicted to yield an average reductions of 0.11 and 0.15 mg/L, respectively. While alum was not assumed to directly alter the rate of internal loading of N, it does appear that some relatively modest indirect reductions in total N were predicted.

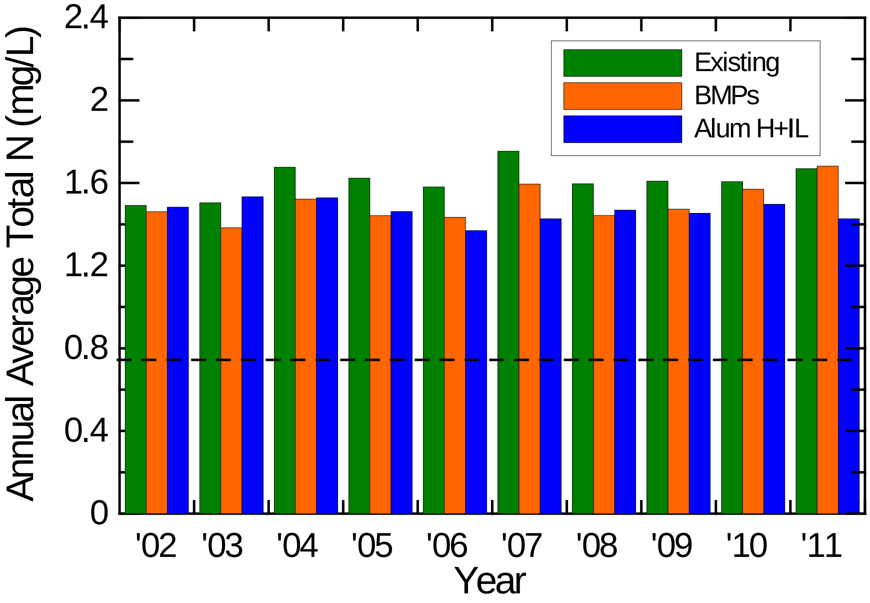


Fig. 2. Volume-weighted annual average total N concentrations in Canyon Lake under (i) model-simulated existing conditions, (ii) with implementation of watershed BMPs achieving 15% external load reductions, and (iii) with alum treatment of hypolimnion with internal PO_4 load reductions.

Alum treatment of the hypolimnion had a surprisingly dramatic effect on predicted annual average chlorophyll a levels in the lake, however (Fig. 3). Based upon these simulation results, such a treatment is sufficient to drive the lake to P-limitation and dramatically reduce chlorophyll concentrations. Detailed inspection of simulation results indicate that some diffusion-dispersion of alum across the thermocline and into the epilimnion occurred as a result of the large concentration gradient; these results are thus thought to reflect water quality from some limited surface treatment as well. (That is, a true hypolimnetic treatment would presumably yield somewhat higher predicted concentrations, although no additional simulations were conducted to assess the influence of depth of alum injection.) Implementation of BMPs also achieved some reductions in annual average chlorophyll a concentrations (Fig. 3), although reductions were much lower than for alum (0.7 - 5.8 μg/L, or 2.2 - 15.8%).

The annual average concentration of DO in the lower portion of the water column exhibited relatively modest interannual variation, ranging from 4-5 mg/L, with no meaningful difference between the existing condition and that when watershed BMPs were in place (Fig. 4). Annual treatment of the hypolimnion with alum was predicted to increase slightly annual average DO concentrations (Fig. 4).

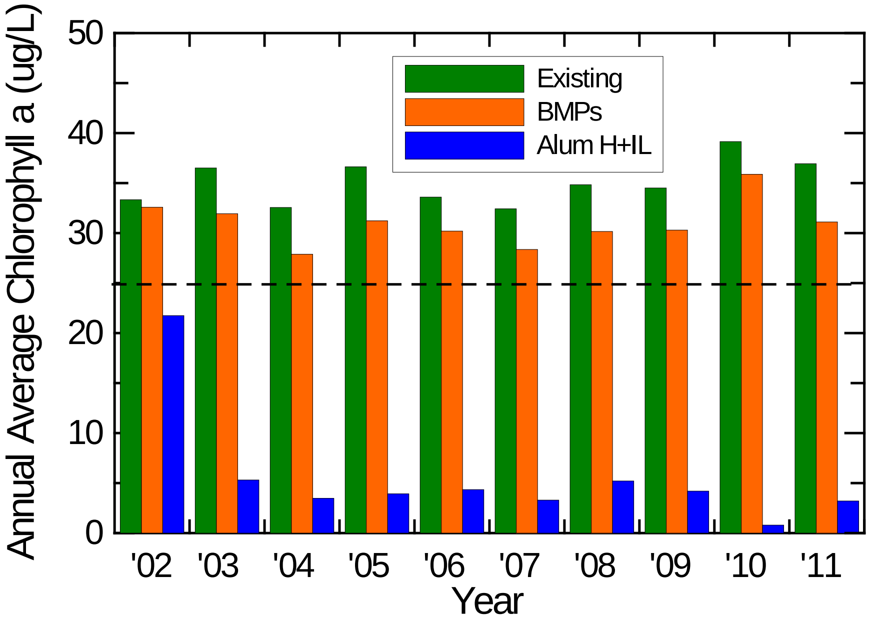


Fig. 3. Epilimnetic annual average chlorophyll a concentrations in Canyon Lake under (i) model-simulated existing conditions, (ii) with implementation of watershed BMPs achieving 15% external load reductions, and (iii) with alum treatment of hypolimnion with internal PO_4 load reductions.

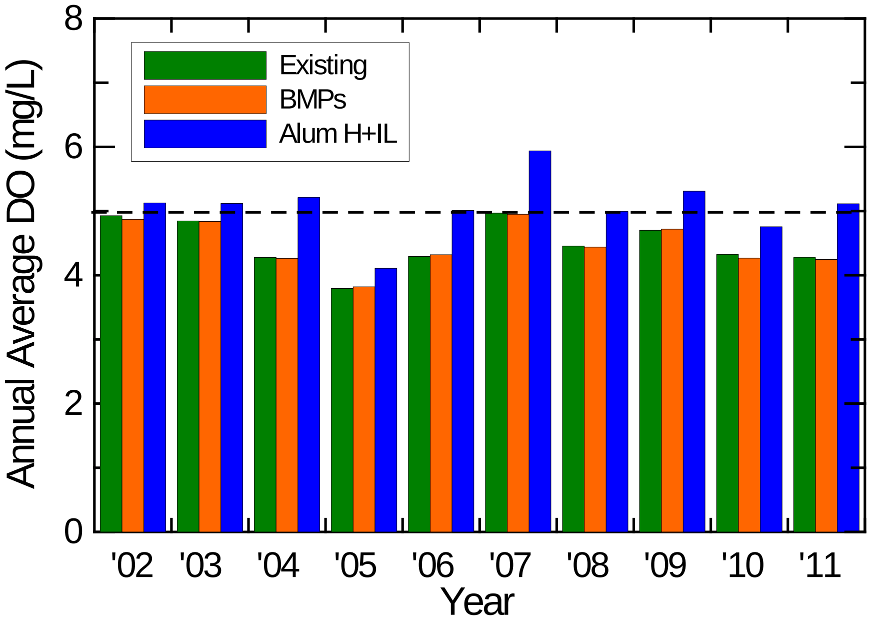


Fig. 4. Volume-weighted annual average dissolved oxygen (DO) concentrations in hypolimnion of Canyon Lake under (i) model-simulated existing conditions, (ii) with implementation of watershed BMPs achieving 15% external load reductions, and (iii) with alum treatment of hypolimnion with internal PO_4 load reductions.

Simulation results were also used to calculate the 10-year average concentrations of total N, total P, chlorophyll a and DO (Table 2). It is useful to compare these values with the TMDL numeric targets of 0.1 mg/L for total P, 0.75 mg/L for total N, and 25 μg/l for chlorophyll a. Here we consider the full range of simulations conducted, including winter alum treatments, BMPs and all combinations of scenarios. We note that, on a 10-yr average, no scenario met either the total P or total N targets, while all alum treatments successfully met the chlorophyll a target.

Table 2. 10-yr average volume-weighted total P and total N concentrations, surface chlorophyll a concentrations, and volume-weighted hypolimnetic DO concentrations.

Scenario	**Total P (mg/L)**	**Total N (mg/L)**	**Chlorophyll a (μg/L)**	**DO (mg/L)**
Existing	0.364±0.061	1.611±0.078	35.0±2.2	4.49±0.37
BMPs	0.314±0.059	1.501±0.091	31.0±2.3	4.47±0.36
Alum H	0.197±0.059	1.468±0.069	9.6±6.3	4.94±0.50
Alum W	0.250±0.087	1.481±0.075	12.2±6.7	4.88±0.42
Alum H + W	0.200±0.065	1.469±0.062	9.1±5.8	4.97±0.50
Alum H + IL	0.146±0.038	1.465±0.048	5.6±5.8	5.07±0.46
Alum H + W + IL	0.151±0.058	1.454±0.045	5.3±5.3	5.08±0.46
BMP + Alum H	0.191±0.045	1.343±0.080	8.6±6.4	4.96±0.49
BMP + Alum W	0.245±0.078	1.343±0.080	11.6±6.7	4.88±0.44
BMP + Alum H + W	0.190±0.045	1.348±0.083	8.6±6.0	4.96±0.45
BMP + Alum H + IL	0.138±0.036	1.336±0.080	4.9±5.5	5.11±0.47
BMP + Alum H+W+ IL	0.152±0.071	1.336±0.081	4.9±5.4	5.09±0.47

These results can also be considered in a probabilistic way through use of cumulative distribution functions (cdf) that describe the frequency of occurrence or exceedance (e.g., Fig. 5a). Here one sees that a 100% probability exists that volume-weighted total P concentrations in Canyon Lake will exceed 0.1 mg/L, with the predicted exceedance frequency decreasing with increasing total P concentrations (Fig 5a). For the existing condition, we see a very high (90%) frequency of exceeding 0.2 mg/L, a 50% probability of exceeding the median value of 0.35 mg/L, and about a 10% frequency in which total P concentrations exceed 0.5 mg/L (Fig. 5a, orange line). Implementation of BMPs shifted the concentrations to slightly lower values, e.g., lowering the median concentration from 0.35 to 0.29 mg/L (Fig. 5a). Total P concentrations nonetheless were predicted to remain quite high with implementation of watershed BMPs.

Treatment of the lake with alum further shifted the cdfs to lower concentrations, e.g., lowering the median total P concentration for hypolimnetic alum treatment (Alum+H) to 0.137 mg/L, and to 0.081 mg/L with winter and hypolimnetic treatments with internal loading control (Alum H+W+IL) (Fig. 5b). Alum treatment in combination with BMPs had a small effect (e.g., reducing the median total P concentration from 0.081 mg/L to 0.075 mg/L for the Alum H+W+IL scenario with BMPs) (Fig. 5c).

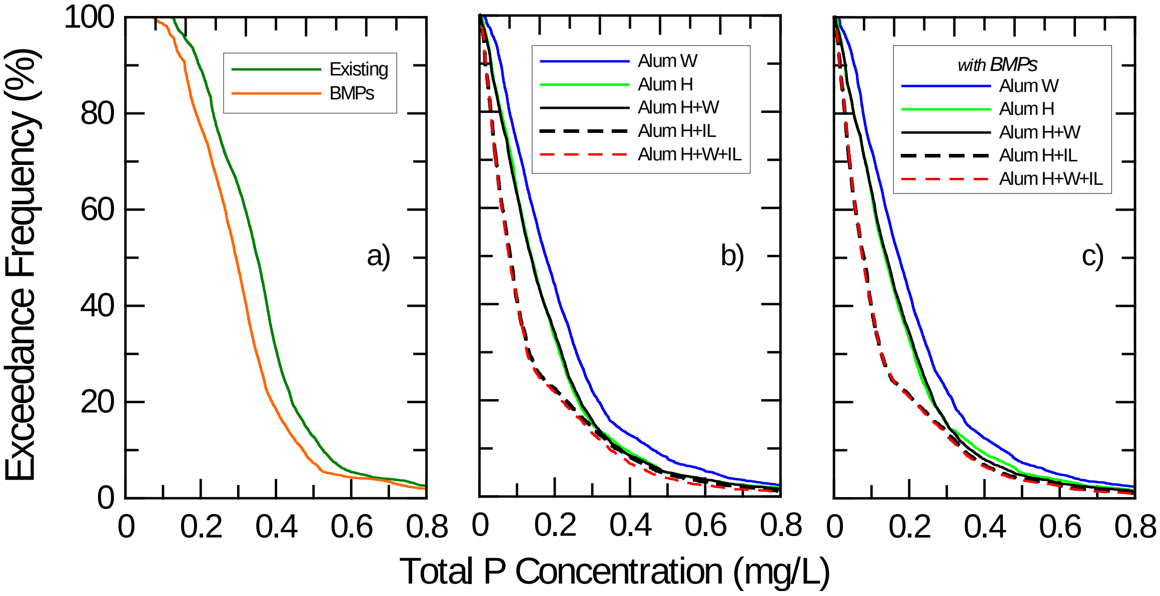


Fig. 5. Cumulative distribution functions showing exceedance frequency as function of simulated total P concentrations in Canyon Lake under (a) existing and BMP scenarios, (b) alum treatments, and (c) BMPs with alum treatments.

Volume-weighted total N concentrations for the different scenarios are also presented using cumulative distribution functions (Fig. 6). As inferred from the annual average (Fig. 2) and the 10-yr average data (Table 2), the different scenarios resulted in generally similar cdfs (Fig. 6). The BMPs shifted the cdfs to slightly (about 0.10 mg/L) lower concentrations relative to existing conditions, with median (50%) exceedance frequency reducing the concentration from 1.56 to 1.45 mg/L (Fig. 6). Alum treatments yielded very little differences in the distribution of predicted total N concentrations and slightly (about 0.03 mg/L) lower than levels predicted for BMPs. Implementation of BMPs in conjunction with alum treatments further shifted the cdfs to lower concentrations; the median concentration dropped to 1.29 mg/L for essentially all combinations of treatment (Fig. 6c).

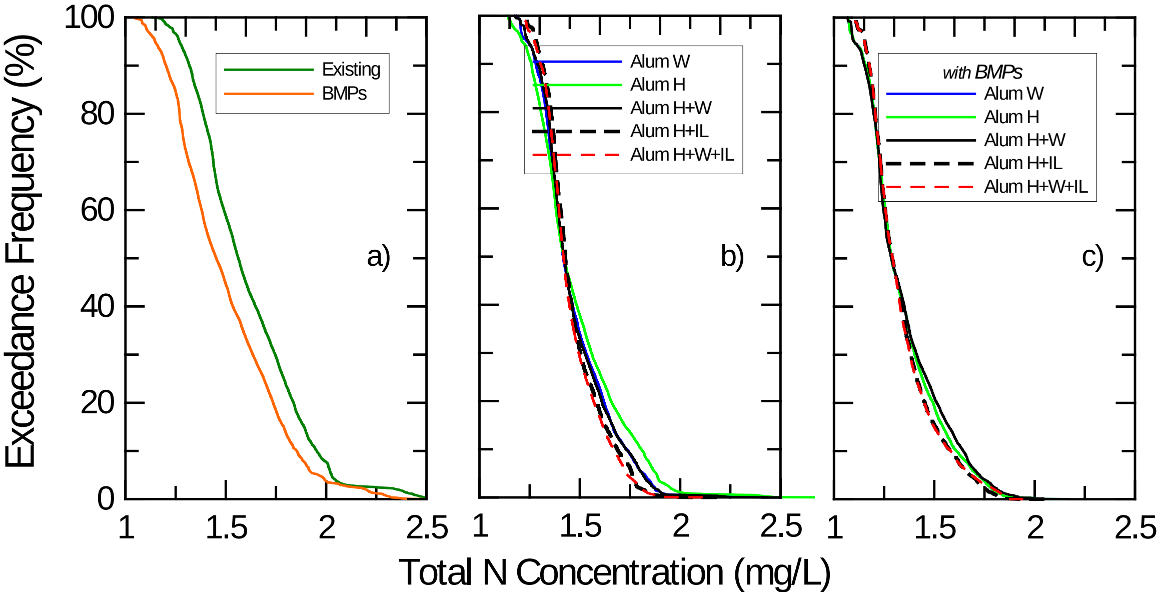


Fig. 6. Cumulative distribution functions showing exceedance frequency as function of simulated total N concentrations in Canyon Lake under (a) existing and BMP scenarios, (b) alum treatments, and (c) BMPs with alum treatments.

The cumulative distribution functions for predicted chlorophyll a concentrations are provided in Fig. 7. For the existing condition (Fig. 7a, green line), we see a very high (95.9%) frequency of exceeding 10 µg/L, although exceedance frequency drops rapidly at higher concentrations. The 50% exceedance frequency for the existing condition corresponds to a median chlorophyll a concentration of 23.5 µg/L. There is a finite probability/frequency of daily chlorophyll a concentrations exceeding 100 µg/L (4.3%). Implementation of BMPs had a small effect on the cdf for chlorophyll a concentration (Fig. 7a, orange line), e.g., shifting the median concentration from 23.5 µg/L to 21.5 µg/L and lowering the predicted frequency of exceeding 100 µg/L from 4.3% to 2.7%.

As indicated in Fig. 3 and Table 2, alum treatments had a dramatic effect on predicted chlorophyll a concentrations relative to existing conditions and with BMPs. This can also be seen clearly in the cdfs (Fig. 7b,c). Whereas chlorophyll a levels exceeded 10 µg/L 95.9% of the time in the simulated existing conditions, the frequency in which chlorophyll a concentrations exceeded 10 µg/L dropped to 37.8% when alum was added at moderate doses to strip PO_4 from the hypolimnion, and to only 16.5% when larger doses sufficient to also help control internal PO_4-P loading (Fig. 7b). Thus, only a small portion of time, generally during fall, did chlorophyll a levels exceed 10 µg/L. Concentrations exceeding 25 µg/L occurred only 12.5% with moderate doses of alum and 4.1% of the time at higher doses that also helped control internal recycling.

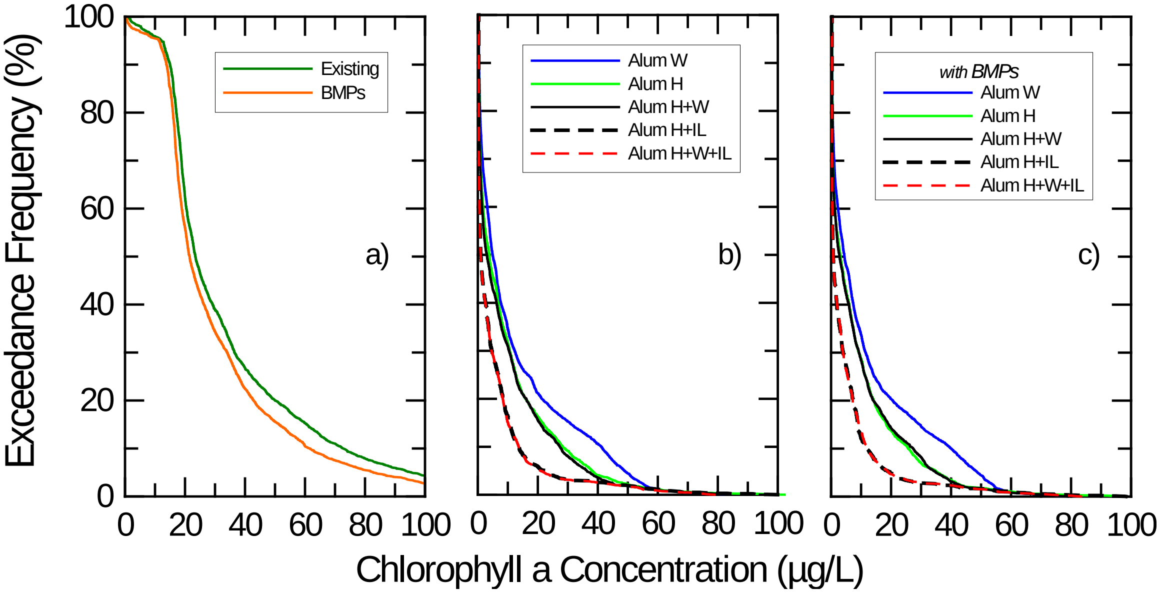


Fig. 7. Cumulative distribution functions showing exceedance frequency as function of simulated chlorophyll a concentrations in Canyon Lake under (a) existing and BMP scenarios, (b) alum treatments, and (c) BMPs with alum treatments.

Exceedance frequencies were also calculated for volume-weighted hypolimnetic DO concentrations (lowermost 7 m of the water column) (Fig. 8). Volume-weighted hypolimnetic DO concentrations were in all cases >2.8 mg/L (i.e., 100% frequency of exceeding this value), with identical median DO concentrations of 3.66 mg/L for both the existing condition and with implementation of BMPs (Fig. 8a). Volume-weighted hypolimnetic DO concentrations ≥5 mg/L were predicted 18.9% of the time under existing conditions and 18.4% with BMPs. Alum treatments were predicted to shift to somewhat higher frequencies the occurrence of DO concentrations ≥5 mg/L (27.6 - 33.2% of the time (Fig. 8b,c). Alum treatments sufficient to provide some control over internal PO_4 recycling in combination with BMPs provided the highest DO levels in the hypolimnion (median value of 3.63 mg/L, 33.2% frequency exceeding 5 mg/L).

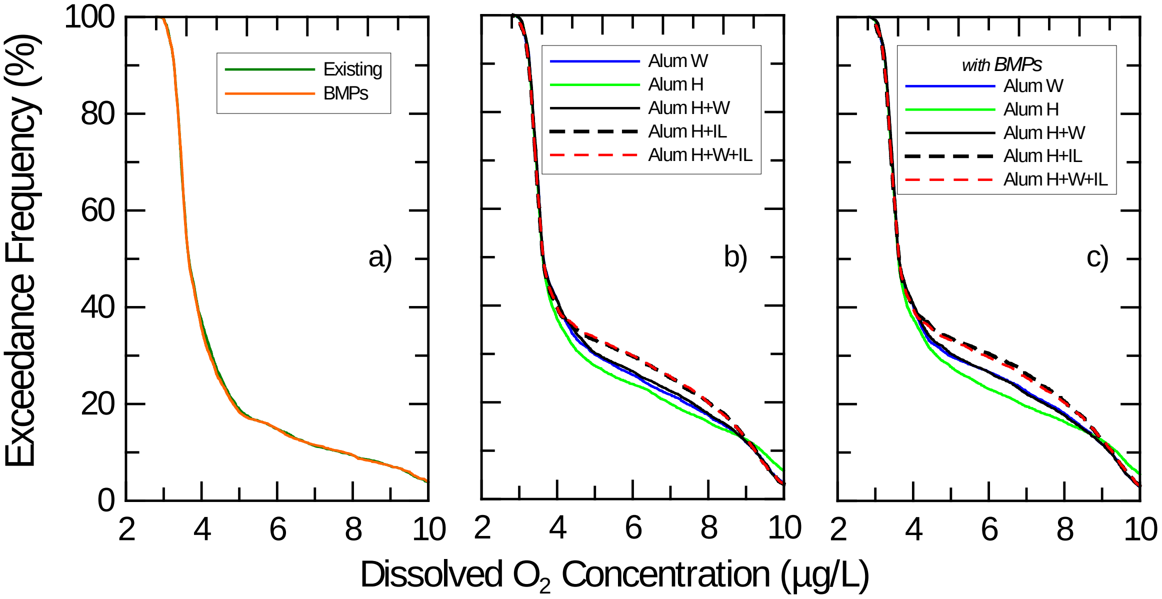


Fig. 8. Cumulative distribution functions showing exceedance frequency as function of simulated total P concentrations in Canyon Lake under (a) existing and BMP scenarios, (b) alum treatments, and (c) BMPs with alum treatments.

Alum Treatment Considerations

Due to the proton production associated with hydrolysis when alum is added to water, and the strong pH dependence of Al solubility, there are some constraints on alum treatment of natural waters. Specifically, the water has to have sufficient alkalinity to maintain circumneutral pH and yet not be too high to favor formation of aluminate ($Al(OH)_4^-$) and thereby diminish efficient formation of $Al(OH)_3$ floc and inhibit PO_4 retention.

Dr. Noblet recently completed jar tests that demonstrated efficient removal of PO_4 from hypolimnetic water from Canyon Lake, with >90% removal at an alum dose between 50-75 mg/L (or 2-3 mg/L Al) (Fig. 9). Such a dose would be expected to consume about 0.3 meq/L of alkalinity, so the lake would be well buffered against strong pH changes at this relatively modest alum dose (Canyon Lake in years past has had alkalinities >3 meq/L, or about 10x that value) (Anderson et al, 2007). The pH of hypolimnetic water decreased only modestly with alum doses up to 100 mg/L (by 0.4-0.7 units, to pH~7.3) (Noblet, 2012), Larger pH reductions were found for waters from East Bay, although outgassing of CO_2 resulted in an increase in pH over time, consistent with other studies (Berkowitz et al., 2005; Anderson et al., 2007).

Dissolved Al concentrations in hypolimnetic waters were found to be increased above background (72-83 µg/L) by a factor of 4-5x (to 236-389 µg/L) with alum addition however (Noblet, 2012). The dissolved Al concentrations following alum addition thus did exceed the chronic toxicity threshold of 87 µg/L, but was well below the acute toxicity threshold of 750 µg/L. It is nonetheless worth noting that the background concentrations were quite close to the chronic threshold. It is also worth noting that the very low DO concentrations and high levels of H_2S in the summer hypolimnion preclude use of this portion of the water column by essentially all aquatic invertebrates, zooplankton and fish. Elevated concentrations of dissolved Al for a moderate period of time in this part of the lake are thus not expected to have any negative ecological consequences. Moreover, dissolved Al concentrations have been found to decrease over time in both laboratory and field settings, including the alum treatment of Big Bear Lake in 2004 (Berkowitz, 2005).

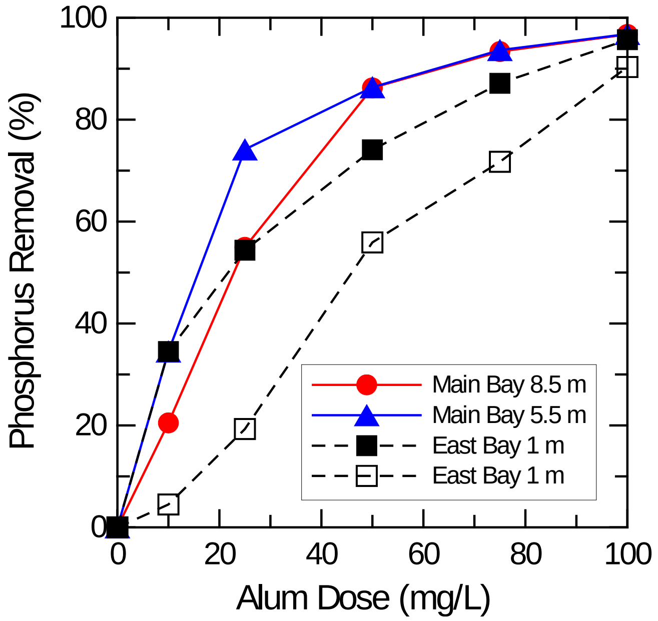


Fig. 9. Phosphorus removal from Canyon Lake water as function of alum dose.

The chemistry of Canyon Lake is not vastly different from that of Big Bear Lake (e.g., pH 8.2, alkalinity 3-4 meq/L), so it is useful to consider that case study further. Specifically, pH and alkalinities in the lake returned to pre-treatment levels within a couple months of treatment, and dissolved Al concentrations, while often near 200 µg/L (0.2 mg/L) during application, quickly decreased to <50 µg/L following the end of the application (due to the large size of the lake and scale of the treatment, application occurred over several weeks). Importantly, no significant short-term or longer-term negative ecological impacts were noted (e.g., no fish mortality was observed).

A small pilot treatment in Papoose Bay with a large (~400-500 mg/L alum) dose was conducted prior to that full-scale treatment; a small logger deployed there found pH to recover to pre-treatment levels within 14 days (dissolved Al measurements were not made, however).

Removal of phosphorus from water collected from East Bay water at about 1 m depth generally demonstrated somewhat lower total P removal efficiencies when compared with the hypolimnetic water; this presumably results from a much larger fraction of P in particulate forms and the higher initial pH that could result in less floc formation. Nonetheless, alum treatment of East Bay waters significantly reduced total P concentrations and lowered turbidity while yielding dissolved Al concentrations below the acute toxicity threshold.

These findings suggest that, with some care, an alum treatment of Canyon Lake should be an effective way to remove phosphorus from the water column and, for surface treatments, should also improve water clarity for at least a short period following application.

Conclusions

This set of simulations indicate:

(i) Implementation of watershed BMPs that achieve a 15% reduction in external loading of N and P was found to yield modest improvements in water quality in Canyon Lake.

(ii) Annual hypolimnetic alum treatment, especially with a sufficient dose to reduce internal PO_4 recycling, provided strong predicted reductions in total P and dramatic reductions in chlorophyll a concentrations.

(iii) Modest alum doses in early winter also yielded significant reductions in total P and chlorophyll levels, although the extent of improvements were lower than predicted with larger hypolimnetic doses.

(iv) BMPs and alum treatments had limited effects on total N and DO concentrations.

(v) Recent jar test results and past experience at Big Bear Lake suggest that, with some care, treatment of Canyon Lake with alum should shift the lake to P-limitation and provide significant reductions in chlorophyll a concentrations.

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A JAR TEST STUDY ON THE USE OF ALUM FOR TURBIDITY AND NUTRIENT REMOVAL IN CANYON LAKE, CA

FINAL REPORT

Submitted to

MWH Americas, Inc.
Arcadia, CA

for

Elsinore Valley Municipal Water District
31315 Chaney St, Lake Elsinore, CA 92531

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December 6, 2012

INTRODUCTION

It has been suggested that treatment of excessive turbidity and algal growth in the east bay and main body of Canyon Lake may be treated with alum (hydrated Aluminum Sulfate, $Al_2(SO_4)_3 \cdot nH_2O$, where n=14-18) a coagulating agent traditionally used in water treatment. In treating water with alum, the natural alkalinity of the water may be used as shown in the following reaction:

$$Al_2(SO_4)_3 \cdot nH_2O + 3Ca(HCO_3)_2 \rightarrow 2Al(OH)_3\downarrow + 3CaSO_4 + nH_2O + 6CO_2 \qquad (1)$$

It is preferable that the natural alkalinity of the water be used to form the aluminum hydroxide precipitate rather than adding a base such a lime both in terms of cost and the inability to control mixing dynamics in a natural lake setting. The pH of Canyon Lake (pH= 9.1 for recently collected east bay samples) is typically above the optimum range for alum treatment (i.e., 5.5-8) [1], but it still may be effective in removing turbidity while not adding to the overall Al concentration of the lake water. Previous studies by Dr. M.A. Anderson's group at UC-Riverside (UCR) [2, 3] have shown that effective doses of alum up to 40 mg Al/L (i.e., ~500 mg alum/L) did not increase the residual water concentration of Al. The pH of alum treated waters dropped significantly within the first hour (8.5 to 6.5) but returned to nearly the ambient pH within 24 hours. The UCR data show that alum doses of up to 10 mg Al/L (or ~125 mg alum/L) have virtually no persistent effect on the pH of the water.

The natural alkalinity of the lake is thus a key parameter for determining the allowable dosing of the water with alum. CSUSB recently collected samples from the east bay at Canyon Lake. Water samples from Station 9 (Road Runner Beach) and Station 10 (Indian Beach) were analyzed for alkalinity and found to have Total Alkalinities 130 mg/L and 150 mg/L as $CaCO_3$, respectively. The corresponding carbonate alkalinities (i.e., the phenolphthalein alkalinity, or pH=8.3) were 36 and 42 mg/L as $CaCO_3$ respectively. The total alkalinities were in fair agreement with the values found by UCR in 2007, which was a lake wide average of 170 mg/L as CaCO3 (i.e., 3.4 meq/L). Quantitative application of equation (1) shows that for every 1 mg/L of alum applied, alkalinity decreases by 0.5 mg/L. Thus our recent alkalinity data suggest that applications of up to 80 mg/L Alum should not decrease the water pH to less than 8.3 at any time during the application. And the UCR data from 2007 suggest that alum doses up to 250 mg/L may have no long term effect on water pH. A survey of environmental engineering textbooks gave typical ranges of 5-50 mg alum/L as being effective for turbidity removal in most waters.

METHODS and MATERIALS

Sampling

Water samples were collected from four stations at Canyon Lake on August 27, 2012, two locations in the Main Body and two locations in the East Bay. Samples from the main body of the lake (8 L) were collected from below the thermocline (i.e., in the hypolimnion). Samples from the east bay were taken at approximately 1 meter depth as the lake at these locations was not stratified. Samples were collected at the same CSUSB monitoring stations that have been used for the past 6 years. The main lake body stations were 7 (near the dam) and 8 (middle of main channel). Samples from the east bay (10 L) were collected at monitoring stations 9 and 10, from the middle of the channel adjacent to Road Runner and Indian beaches, respectively.

All water samples were collected using a 4.2 liter vertical beta type van Dorn sampler (with acrylic tube, Wildlife Supply Company). Repeat grab samples were collected at the appropriate depths until the desired volume was obtained. Samples were transferred to pre-cleaned 2.5 liter clear glass or 4.0 liter amber glass bottles. Samples were stored on ice in ice chests until returned to the lab, and then were stored in a walk-in refrigerator at 4°C until analyzed.

Depth profiles at each station were measured at 1 meter intervals using a Hach Hydrolab DS-5 water quality sonde. Parameters measured included depth, temperature, electrical conductivity, ORP, and turbidity. Dissolved oxygen data were not obtained as the LDO probe on the Hydrolab was not functioning properly. Data from the depth profile at each station were used to determine in the field at what depth to take the samples.

Laboratory Analyses

Jar Testing

Jar tests were performed on the collected samples using 1.0 L samples, on a six stirrer Phipps and Byrd programmable jar test apparatus (Figure 1). Jar test were performed as follows: The appropriate amount of 10,000 ppm alum stock was added to each sample, and flash mixed at 220 rpm for 1.25 minutes, then followed by flocculation at 25 rpm for 30 minutes. The samples were then allowed to settle for 2-3 hours until all of the floc had fully settled. Before and after treatment samples were measured for pH, temperature, turbidity, conductivity, dissolved aluminum concentration, total organic carbon (TOC), total nitrogen and total phosphorus. The goal of the testing was to identify the dose of alum required to achieve a turbidity of less than 1.0 NTU. The tests were performed at doses of 0 (control, before), 10, 25, 50, 75, and 100 mg/L Alum. Based upon the results of the initial testing, two additional alum concentrations were tested, 125 and 150 mg/L.

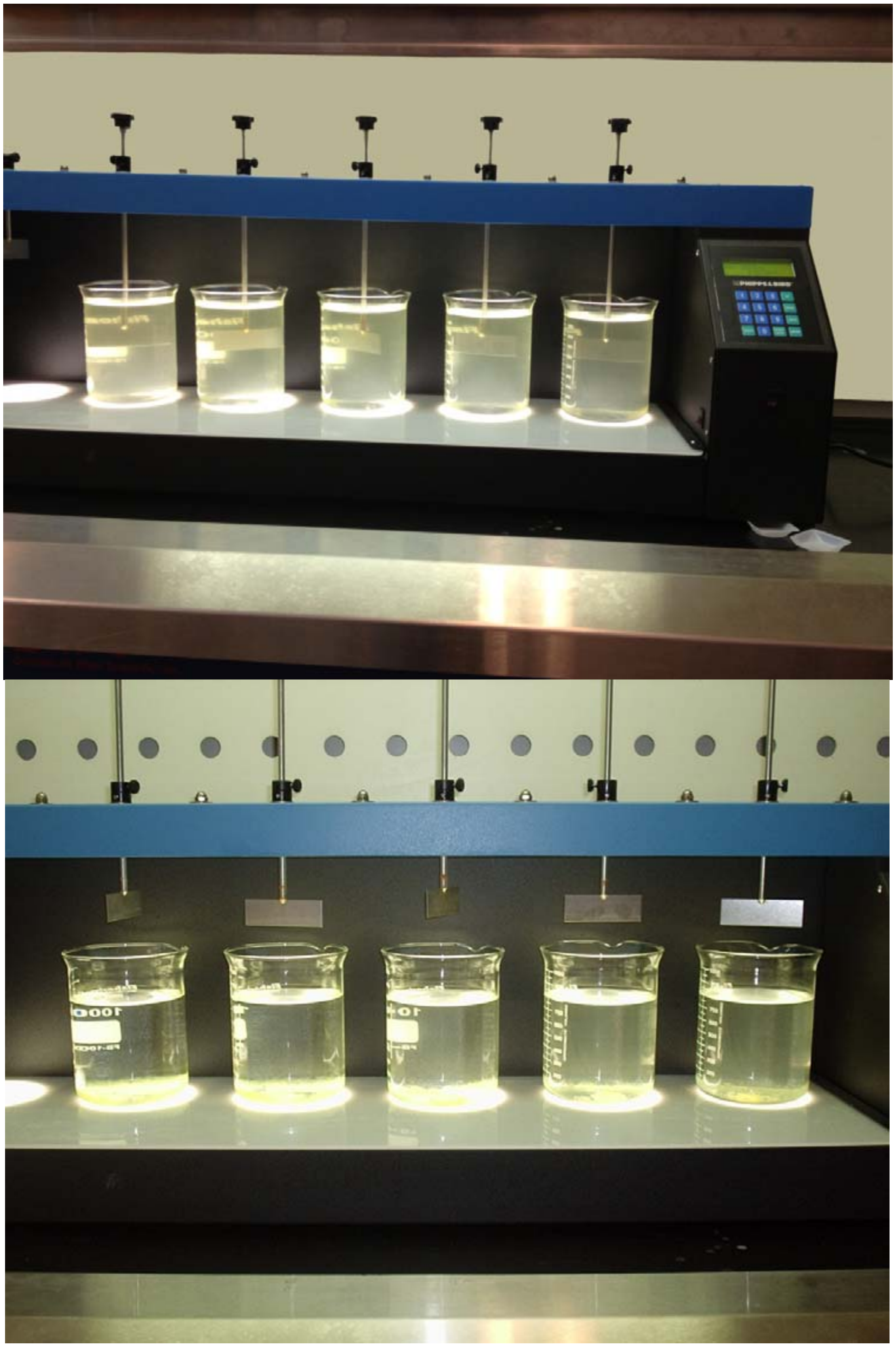

Figure 1. Phipps and Byrd jar testing apparatus used in this study, at the beginning (top) and at the end of the test procedure after settling of the flocs (bottom).

Water Quality Analyses

In the laboratory all water quality parameters were measured using methods and protocols as described in standard EPA methods or in *Standard Methods for the Examination of Water and Wastewater*, 21st edition [4]. The temperature, pH and conductivity were measured using a WTW 350i multiparameter field probe. Turbidity was measured with a HF Scientific MicroPTW portable turbidimeter. TOC was measured on a Teledyne Tekmar Apollo 9000 combustion TOC analyzer. The total nitrogen (TN) and total phosphorus (TP) were measured on a LACHAT Quickchem 8500 Flow Injection Analysis (FIA) system. Samples were processed using the LACHAT method of persulfate digestion followed by simultaneous TN/TP analysis. The dissolved aluminum concentrations before and after treatment were measured using a Perkin Elmer AAnalyst 600 graphite furnace atomic absorption spectrophotometer, using the EPA Method 200.9 protocol [5]. Because of the critical nature of the dissolved aluminum concentrations, blank samples (i.e., deioniozed water) were subjected to the entire jar testing procedure to ensure that there was no aluminum contamination introduced by either laboratory cleaning and handling procedures or the testing apparatus. None of the blank samples analyzed showed detectable levels of aluminum.

RESULTS and DISCUSSION

Field Data

The results of the parameters measured in the field are shown in Tables 1-4. The results show that station 7 in the deepest part of the lake near the dam was well-stratified, as usual for that the time of year. Station 8 also in the main channel of the Lake was not really stratified with a thermocline appearing at approximately 1.5 meters above the bottom. Samples were collected at 8.5 meters and at 5.5 meters for stations 7 and 8, respectively. Plots of the temperature depth profiles for stations 7 and 8 are shown in Figures 2 and 3. Samples were collected at stations 9 and 10 at approximately 1 meter below the surface.

Laboratory Water Quality Data

The results of the laboratory water quality analyses are shown in Tables 5-9. For the hypolimnion samples from stations 7 and 8, a dose of 25-50 ppm alum is sufficient to achieve a turbidity of ≤1.0 NTU. However, doses of 100 ppm are required to achieve the lowest dissolved Al concentrations, and maximum phosphorus removal. For the east bay water samples, it appears that a dose of 100 ppm alum is required to achieve both turbidity reduction and the lowest dissolved Al concentrations, and maximum phosphorus removal. It is noteworthy that the pH of the sample from station 10 (farthest into the east bay) dropped almost two pH units with a 100 ppm alum dose. However, pH and turbidity measurements taken after 24 hrs showed that pH had gone back up by 0.6 pH units while turbidity dropped slightly.

These initial results show that alum is very effective in reducing the turbidity and phosphorus, and to lesser extent nitrogen content of the waters from throughout the lake, but the residual aluminum concentrations exceed the EPA chronic ambient water quality criterion for protection of aquatic biota, which is 87 µg/L for chronic toxicity (the acute toxicity criterion is 750 µg/L) [6]. In response to the initial results showing dissolved Al concentrations above the chronic criterion, two additional concentrations of alum were evaluated, 125 and 150 mg/L alum. The results of the higher concentrations showed that an alum dose of 150 mg/L was able to reduce the residual dissolved Al concentrations significantly to a range of 89-106 µg/L. This is only slightly above the chronic criterion and thus these residual concentrations may be acceptable. The EPA website showing the current ambient water quality criteria for protection of aquatic life has three footnotes associated with the water quality criteria for Al [6]:

1. The value of 87 µg/l is based on a toxicity test with the striped bass in water with pH = 6.5–6.6 and hardness <10 mg/L. Data in "Aluminum Water-Effect Ratio for the 3M Plant Effluent Discharge, Middleway, West Virginia" (May 1994) indicate that aluminum is substantially less toxic at higher pH and hardness, but the effects of pH and hardness are not well quantified at this time.
2. In tests with the brook trout at low pH and hardness, effects increased with increasing concentrations of total aluminum even though the concentration of dissolved aluminum was constant, indicating that total recoverable is a more appropriate measurement than dissolved, at least when particulate aluminum is primarily aluminum hydroxide particles. In surface waters, however, the total recoverable procedure might measure aluminum associated with clay particles, which might be less toxic than aluminum associated with aluminum hydroxide.
3. EPA is aware of field data indicating that many high quality waters in the U.S. contain more than 87 µg aluminum/L, when either total recoverable or dissolved is measured.

These statements highlight the fact that predicting Al toxicity in surface waters is complicated. It was decided to measure dissolved Al concentrations rather total Al concentration due to concern expressed in the latter part of footnote 2. Given the statements in footnotes 1 and 3, and the fact that Canyon Lake water has slightly higher pH after treatment, and relatively high hardness, the levels of residual aluminum of 89-106 µg/L may be acceptable for the protection of aquatic life within the lake.

SUMMARY OF RESULTS

The results of this study show that in-lake treatment with alum may be an effective way to remove both existing turbidity and nutrients from Canyon Lake water. The removal of nutrients will reduce the potential for future water quality problems in the lake. For Stations 7 and 8 below the thermocline, and for Station 9, an alum dose of 50 mg/L was sufficient to drop turbidity to less than 1.0 NTU. This dose also resulted in reductions in total nitrogen of 6%, 36%, and 28% for stations 7, 8 and 9 respectively. Even greater relative reductions in total phosphorus were achieved; with reductions of 86%, 86%, and 74% for stations 7, 8 and 9, respectively. The water samples from station 10 required a higher alum dose of 100 mg/L to drop the turbidity to less than 1.0 NTU. The 100 mg/L alum dose resulted in reductions in total nitrogen and total phosphorus of 64% and 92%, respectively. All of the alum doses studied resulted in residual dissolved aluminum concentrations below the EPA acute toxicity criterion for the protection of aquatic life, 750 µg/L. An alum dose of at least 150 mg/L is required to reduce the residual dissolved aluminum concentration in the treated waters to levels close to the EPA chronic ambient water quality criterion for the protection of aquatic life. Even higher doses of alum may be effective in lowering the residual Al concentrations, but practical doses are limited by the drop in pH and the natural alkalinity of the lake. While the results of these laboratory studies are promising, limited in-lake treatment studies should be conducted to determine the actual effects of alum treatment on the *in situ* water quality in Canyon Lake.

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3. Anderson, M.A. *Predicted Effects of In-Lake Treatment on Water Quality in Canyon Lake*, December 31, 2007. Final Report to San Jacinto Watershed Council.
4. APHA, AWWA. *Standard Methods for the Examination of Water and Wastewater,* Centennial 21st ed. 2005.
5. EPA Method 200.9, *Trace Elements in Water, Solids, and Biosolids by stabilized temperature graphite furnace atomic absorption spectrometry revision 3.0*. 1998.
6. EPA Ambient Water Quality Criteria for the protection of aquatic life: http://water.epa.gov/scitech/swguidance/standards/criteria/current/index.cfm.

Table 1. Depth profile data for Station 7.

Station 7 8/27/2012 8:44 am

Depth (m)	**Temp** (C^{o})	**pH**	**ORP** (mV)	**EC** (mS/cm)	**Turb** (NTU)
0.5	28.5	8.60	199	1088	5.3
1.0	28.5	8.62	189	1087	5.9
2.0	28.5	8.58	185	1087	6.1
3.0	28.5	8.56	183	1088	5.8
4.0	28.5	8.48	182	1090	5.4
5.0	27.0	7.39	213	1096	10.7
6.0	23.3	7.11	290	1041	10.5
7.0	19.7	7.04	317	1006	7.2
8.0	17.6	7.05	329	991.4	6.3
9.0	16.1	7.00	335	985.3	5.8
10.0	15.5	6.97	340	984.6	5.1
11.0	15.2	6.94	343	990.3	5.9
12.0	15.0	6.85	346	992.8	6.5
12.5	14.9	6.85	348	993.3	11.6
13.0	Bottom				

Table 2. Depth profile data for Station 8.

Station 8 8/27/2012 9:30 am

Depth (m)	**Temp** (C^{o})	**pH**	**ORP** (mV)	**EC** (mS/cm)	**Turb** (NTU)
0.5	28.7	8.59	40	1095	5.9
1.0	28.7	8.58	34	1095	6.5
2.0	28.6	8.55	33	1096	6.0
3.0	28.5	8.51	33	1095	6.0
4.0	28.4	8.40	36	1095	6.8
5.0	27.9	7.64	204	1103	9.3
6.0	22.15	7.08	310	1033	10.9
6.4	bottom				

Table 3. Depth profile data for Station 9.

Station 9 8/27/2012 10:00 am

Depth (m)	**Temp** (C^{o})	**pH**	**ORP** (mV)	**EC** (mS/cm)	**Turb** (NTU)
0.5	28.2	8.78	40	1255	13.0
1.0	28.2	8.64	31	1256	12.7
2.0	27.9	8.40	37	1259	12.0
3.0	27.8	8.46	35	1255	11.2
4.0	26.3	7.01	313	1274	19.7
5.0	20.2	6.86	352	1285	19.7
5.5	Bottom				

Table 4. Depth profile data for Station 10.

Station 10 8/27/2012 10:30 am

Depth (m)	**Temp** (C^{o})	**pH**	**ORP** (mV)	**EC** (mS/cm)	**Turb** (NTU)
0.5	28.3	8.71	10	1272	19.7
1.0	28.1	8.68	10	1278	20.0
2.0	27.6	8.46	18	1293	21.4
2.2	Bottom				

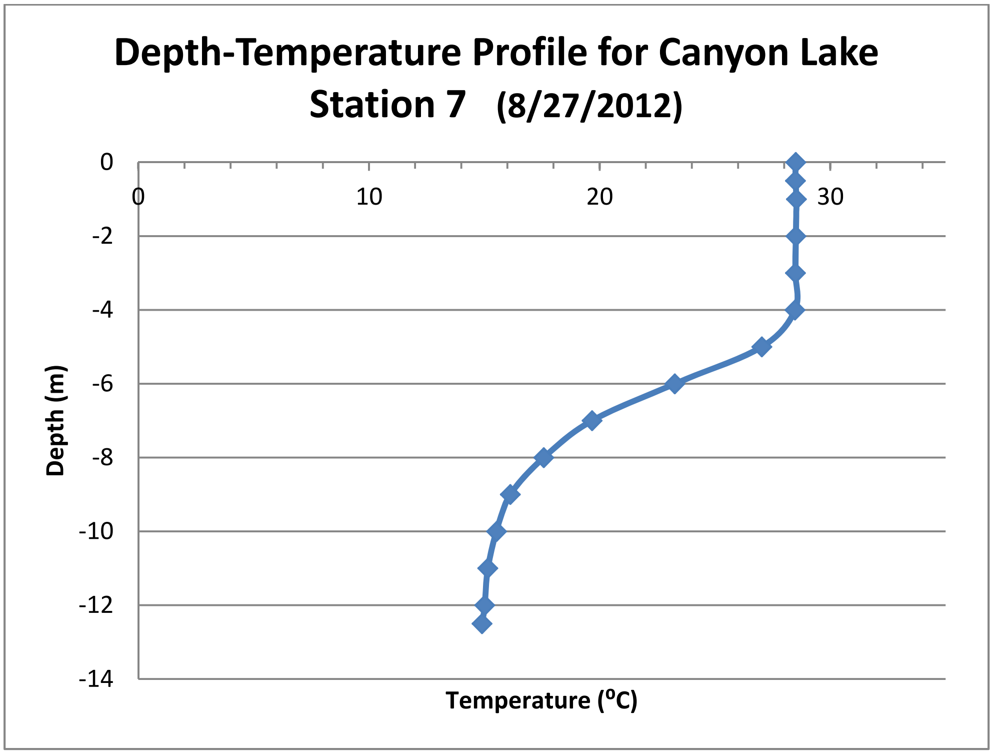

Figure 2. Depth-Temperature profile for Station 7, Canyon Lake.

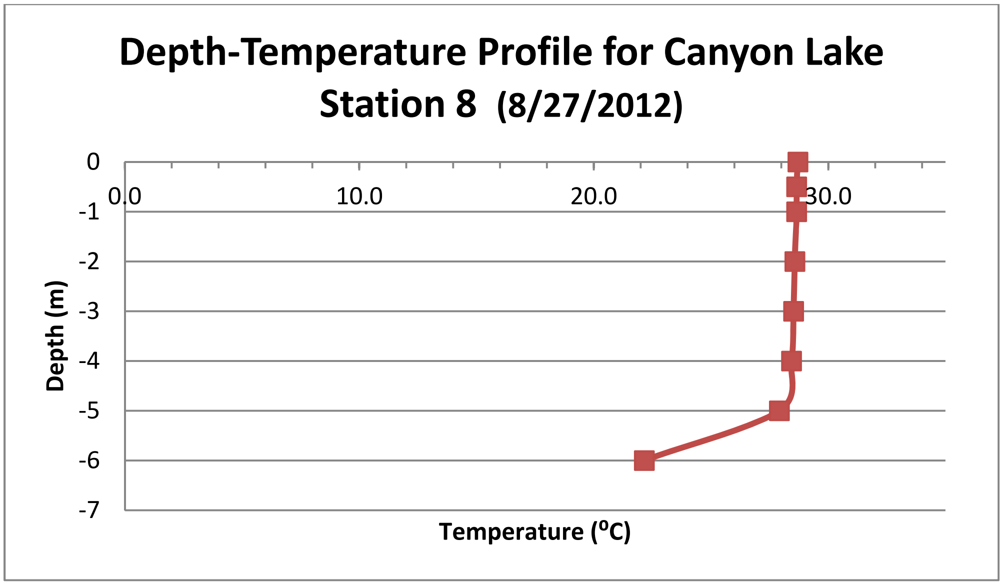

Figure 3. Depth-Temperature profile for Station 8, Canyon Lake.

Table 5. Jar test results for water from Station 7.

Station 7 (hypolimnion, 8.5 m)

Alum Dose (mg/L)	pH	Temp (^{o}C)	Turbidity* (NTU)	Cond. (µS/cm	Diss. Al (µg/L)	TOC (mg/L)	Tot N (mg/L)	Tot P (mg/L)
0	7.57	22.1	90.25	1032	72	11.1	2.290	1.010
10	7.45	21.3	1.51	1030	289	12.9	2.310	0.803
25	7.50	21.6	0.91	1032	366	12.1	2.210	0.455
50	7.44	21.5	0.54	1036	321	10.9	2.160	0.139
75	7.30	21.7	0.43	1037	298	9.2	2.060	0.067
100	7.29	21.3	0.89	1042	258	10.8	1.770	0.033
125	7.05	21.2	0.18	1037	86			
150	7.00	21.2	0.22	1044	89			

* High Turbidity was due to a precipitation reaction that occurred during storage at 4^{o}C.
Field turbidity was around 6.0 NTU

Table 6. Jar test results for water from Station 8.

Station 8 (hypolimnion, 5.5 m)

Alum Dose (mg/L)	pH	Temp (^{o}C)	Turbidity (NTU)	Cond. (µS/cm	Diss. Al (µg/L)	TOC (mg/L)	Tot N (mg/L)	Tot P (mg/L)
0	7.97	22.10	5.89	1100	83	14.5	1.100	0.313
10	8.06	22.20	2.00	1117	374	15.0	0.960	0.205
25	7.91	21.60	1.03	1124	389	14.7	0.809	0.081
50	7.66	22.00	0.71	1118	355	12.8	0.705	0.043
75	7.41	21.60	0.62	1118	276	11.3	0.676	0.020
100	7.31	22.00	0.18	1127	236	9.7	0.688	0.010
125	7.16	21.00	0.16	1130	106			
150	7.01	21.00	0.18	1141	101			

Table 7. Jar test results for water from Station 9.

Station 9 (East Bay, Road Runner Beach)

Alum Dose (mg/L)	pH	Temp (^{o}C)	Turbidity * (NTU)	Cond. (µS/cm	Diss. Al (µg/L)	TOC (mg/L)	Tot N (mg/L)	Tot P (mg/L)
0	8.55	21.8	2.17	1270	134	18.7	1.348	0.098
10	8.01	21.3	1.96	1299	287	20.4	1.460	0.064
25	7.81	21.6	1.37	1290	331	19.5	1.210	0.045
50	7.64	21.3	0.95	1290	285	16.6	0.971	0.025
75	7.52	21.8	0.52	1305	231	14.4	0.813	0.013
100	7.33	21.3	0.69	1299	146	13.2	0.647	0.004
125	7.00	20.9	0.19	1306	107			
150	6.81	20.9	0.23	1299	104			

* Turbidity changed during storage at 4^o C. Field turbidity was 12.7

Table 8. Jar test results for water from Station 10.

Station 10 (East Bay, Indian Beach)

Alum Dose (mg/L)	pH	Temp (^{o}C)	Turbidity* (NTU)	Cond. (µS/cm	Diss. Al (µg/L)	TOC (mg/L)	Tot N (mg/L)	Tot P (mg/L)
0	8.56	22.1	7.84	1277	17	20.7	1.635	0.106
10	8.06	22.1	4.60	1286	607	17.3	1.480	0.094
25	7.66	21.8	3.55	1287	511	19.7	1.310	0.079
50	7.17	21.9	1.77	1294	456	18.1	0.994	0.043
75	6.95	22.0	1.47	1296	441	16.0	0.801	0.028
100	6.69	22.0	0.71	1297	280	13.8	0.585	0.009
125	6.91	21.1	0.29	1332	136			
150	6.76	20.9	0.24	1329	106			

* Turbidity changed during storage at 4^o C. Field turbidity was 20.0 NTU

Table 9. The pH and turbidity values for Station 10 jar test after 24 hours.

Alum Dose (mg/L)	pH	Turbidity (NTU)
0	8.56	7.84
10	8.10	4.04
25	7.88	2.70
50	7.63	1.85
75	7.46	1.46
100	7.30	0.53

Attachment D
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Tables

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Attachment D
Existing Nutrient Source Control Programs

D.1 Introduction

The MS4 permittees within the watersheds draining to Canyon Lake and Lake Elsinore are in compliance with the MS4 permit requirements applicable to this area of Riverside County. Compliance activities include implementation of both non-structural and structural BMPs. This section documents permit-related activities implemented by the MS4 permittees since January 1, 2005, essentially the time period since adoption of the Nutrient TMDLs (adopted December 20, 2004). Implementation of these activities has supported efforts to reduce the runoff of nutrients from urban areas covered by the MS4 permit, thus providing water quality benefits to the area.

D.2 Non-Structural BMPs

Non-structural BMPs that can reduce the presence of nutrients in urban runoff include:

- Public Education and Outreach
- Ordinance Adoption
- Inspection and Enforcement Activities
- Street Sweeping
- MS4 Facility Inspection and Cleaning Programs
- Septic System Management
- Fertilizer Application Management

The following sections describe each of the above BMPs. Where it is possible to quantify water quality benefits, this information has been included in the CNRP compliance analysis (see Section 3). Where it is not possible to quantify the benefits, the expected water quality benefits are considered qualitatively as part of the margin of safety that is implicit in the compliance analysis calculations.

D.2.1 Public Education and Outreach

The MS4 permittees collectively participate in public education and outreach efforts that promote stormwater pollution prevention. Although outreach events may not specifically focus on reducing nutrient levels, events which highlight the elimination or reduction of debris or pollutants from entering the MS4 or runoff have the potential to reduce nutrient loads.

Emphasis of BMPs is on management of pet waste, fertilizer use, proper operation and maintenance of septic systems, and prevention of sedimentation. Example public education BMPs and outreach activities in the watershed that reduce nutrients in urban runoff include (see MS4 Program Annual Reports for more details regarding ongoing public education and outreach activities):

- *What's the Scoop* and *After the Storm* brochures address the need to pick up animal waste and to dispose of it properly.
- *After the Storm* brochure addresses the need to pick up pet wastes and minimize sedimentation.
- RCFC&WCD, in partnership with San Bernardino County, sponsored a 1-hour episode of a PBS show for kids called *Curiosity Quest.* The episode focused on the impacts residential activities can have on stormwater, e.g., improper pet waste disposal.
- A school activity book and “Fancy Fin” presentation discuss proper disposal of pet waste.
- The *Keep Our Water Clean* video focuses on the proper disposal of pet waste and proper uses of fertilizers and avoiding excess runoff from sprinklers.
- The adult-focused presentation, *Only Rain Down the Storm Drain*, discusses various pollutant concerns associated with stormwater. The Agricultural Commissioner, University of California Riverside Cooperative Extension and local nurseries assist with distribution of materials. Mission Resource Conservation District presentations discuss the effects fertilizers can have on local waters.
- Construction, municipal, industrial/commercial and new development training activities focus on the need to address pollutant sources, including nutrients, erosion control and sedimentation, in the watershed. A specific section of the municipal employee training focuses on the need to manage nutrients in the watershed.
- RCFC&WCD contracts with S. Groner and Associates to distribute pet waste information in pet stores, veterinarian clinics, kennels and pet grooming facilities.
- The MS4 program coordinates with the Riverside County Animal Control Department and private “no kill” pet shelters to distribute *What’s the Scoop* and *After the Storm* brochures to families adopting pets at these shelters.
- The MS4 program distributes a variety of materials that promote reduction of pollutants at the source. Distributed materials include:
- Landscape and Gardening brochures;
- Tips for Maintaining a Septic Tank System brochure *(information is also included in the County*’s Septic Tank Guide Booklet);
- *Tips for Horse Care* brochure that addresses equestrian care and management; and
- Dust pans featuring the Only Rain Down the Storm Drain message to promote dry cleaning of driveways and impervious surfaces.

- An Earth Day flyer (April), offers user-friendly suggestions for reducing the use of chemicals, considering integrated pest management in gardening, and understanding problems with unrecovered pet waste.

- The County's *Environmental Calendar* includes a variety of information regarding stormwater management and promotes the "Only Rain Down the Storm Drain" message and provides the stormwater program's 800 hotline number to report water quality concerns.

- RCFC&WCD does not allow the disposal of pet waste or other trash within its facilities. Signage has been installed at access gates to discourage illegal dumping and encourage the reporting thereof. At the start of the program, RCFC&WCD purchased "Dogipots" (containers that hold pet waste bags) and installed them in County Parks. Upkeep and additional purchases of Dogipots are the responsibility of County Park staff.

It is not possible to directly quantify reductions in nutrient loads in urban runoff to specific public education and outreach activities. Accordingly, the water quality benefits that occur as a result of these activities are considered qualitatively as part of the margin of safety associated with implementation of the CNRP.

D.2.2 Ordinance Adoption

The MS4 permittees in the Santa Ana Region have adopted ordinances which provide legal authority to control non-permitted discharges from entering MS4 facilities. These ordinances prevent the following types of discharges to MS4 facilities:

- Sewage to MS4 facilities

- Wash water resulting from hosing or cleaning of gas stations and other types of automobile stations

- Discharges resulting from the cleaning, repair, or maintenance of equipment, machinery or facilities, including motor vehicles, concrete mixing equipment, and portable toilet servicing

- Wash water from mobile auto detailing and washing, steam and pressure cleaning, and carpet cleaning

- Water from cleaning of municipal, industrial, and commercial areas including parking lots, streets, sidewalks, driveways, patios, plazas, work yards and outdoor eating or drinking areas, containing chemicals or detergents and without prior sweeping

- Runoff from material storage areas or uncovered receptacles that contain chemicals, fuels, grease, oil or other hazardous materials

- Discharges of runoff from the washing of toxic materials from paved or unpaved areas

- Discharges from pool or fountain water containing chlorine, biocides, or other chemicals; pool filter backwash containing debris and chlorine

- Pet waste, yard waste, debris, and sediment

- Restaurant or food processing facility wastes such as grease, floor mat and trash bin wash water, and food waste

Table D-1 summarizes the ordinances adopted by jurisdiction. Most ordinance updates in recent years have focused on landscape water use efficiency. Of particular note in Table D-1 are the ordinances adopted by (a) City of Canyon Lake (Ordinance No. 134U), which prohibits animal and human waste and illegal dumping in Bureau of Land Management lands in the vicinity of Canyon Lake and Ordinance No. 138U which requires proper disposal of pet waste by owners; and (b) Riverside County Ordinance, which prohibits septic tanks in specified areas in Quail Valley (now incorporated as part of City of Menifee) and requiring connection to existing septic systems to sewer systems.

It is not possible to directly quantify reductions in nutrient loads in urban runoff to ordinance adoption. Accordingly, the water quality benefits that occur as a result of the adoption and implementation of ordinances are not included in the set of BMPs used to demonstrate compliance.

D.2.3 Inspection and Enforcement Activities

MS4 permittees conduct inspections of commercial and industrial facilities as part of municipal NPDES programs to assess compliance of facilities with local stormwater ordinances and, where applicable, potential noncompliance with California's General Permit for Storm Water Discharges Associated with Industrial Activities. In evaluation of these programs for water quality benefits, restaurant inspections are of particular interest since restaurant activities are potential sources of nutrients.

Riverside County MS4 permittees implement a Commercial/Industrial Compliance Assistance Program (CAP) to conduct focused outreach to restaurants, automotive repair shops and certain other commercial and industrial establishments to encourage implementation of stormwater BMPs and facilitate consistent and coordinated enforcement of local stormwater quality ordinances. This program is conducted regionally through the County Department of Environmental Health. Site visits include use of survey checklists to document stormwater management practices for each facility.

In Riverside County, there are approximately 6,750 retail food facilities. Inspections are conducted one to three times per year. In addition, CAP has a specific compliance survey for food facilities to verify that:

- Oil and grease wastes are not discharged onto a parking lot, street or adjacent catch basin
- Trash bin areas are clean; bin lids are closed, not filled with liquid, and bins have not been washed out into the MS4
- Floor mats, filters and garbage containers are not washed in adjacent parking lots, alleys, sidewalks, or streets and that no wash water is discharged to MS4s
- Parking lot areas are cleaned by sweeping, not by hosing down, and that facility operators use dry methods for spill cleanup

Table D-1. Existing Ordinances Adopted by MS4 Permittees in the San Jacinto River Watershed

Jurisdiction	Ordinance Name	Key Provisions
Beaumont		No data /info submitted
Canyon Lake	Landscape Water Use Efficiency	Establishes landscape water use efficiency requirements
	Ordinance No. 107	City permit required for all commencing projects that can lead to illegal discharge to Canyon Lake
	Ordinance No. 123	Adopts 2007 California Plumbing Code, prevent leaks and spillage within City of Canyon Lake
	Ordinance No. 134U	Prohibit animal, human waste, and illegal dumping in undeveloped City jurisdiction - Bureau of Land Management (BLM) lands in vicinity of Canyon Lake
	Ordinance No. 138U	Establishes in municipal code requirements for proper disposal of animal waste by a pet owner/keeper from any public or private property regardless of property ownership or possession
Hemet	Water Efficient Landscape Ordinance	Promote water conservation through efficient irrigation and climate appropriate plant material
Lake Elsinore	Water Efficient Ordinance No. 19.08	Reduce water demand from landscapes; attain water efficient landscape goals
Menifee	Landscape Water Use Efficiency Ordinance	Purpose of ordinance is to eliminate irrigation overspray and runoff
Moreno Valley	Ordinance No. 826	Establishes landscape and irrigation design standards
	Ordinance No. 827	Repeal and reenact stormwater urban runoff management & discharge control
Murrieta	Ordinance No. 335-05	NPDES stormwater runoff quality
City of Riverside	Water Conservation	Addresses irrigation water leaving the property
County of Riverside	Water Efficient Landscaping – Ordinance 859	Addresses irrigation water leaving the property with greater than 1 acre of landscaping
	Ordinance 427	Regulates land application of manure
	Ordinance 856	Prohibits septic tanks in specified areas in Quail Valley, requiring connection to existing septic systems to sewer
	Ordinance 650	Regulates discharge of sewage in unincorporated areas
San Jacinto	Water Conservation – Ordinance 09-16	Prohibits excessive water flow or runoff onto sidewalks, driveways, streets, alleys, and gutters
Wildomar	Ordinance adoption at incorporation	City adopted County of Riverside ordinances as they existed on July 1, 2008 (date of City incorporation); includes septic system management

Each Permittee also develops an inventory of commercial facilities that include industries such as nurseries and greenhouses as well as landscape and hardscape installation. Having a list of these types of businesses is critical when conducting inspections and training regarding practices which may be sources of nutrients.

Additional inspections conducted by individual jurisdictions since January 1, 2005 that provide benefits to water quality include:

- City of Canyon Lake conducted 3 commercial inspections in 2011 calendar year and inspected a Property Owners Association-owned campground, which has close proximity to Canyon Lake.
- In addition to the commercial and industrial facility programs, Menifee conducts 120 inspections yearly. The increase in inspections provides increased public and business awareness of stormwater pollution which in turn reduces the potential for pollutants to enter the storm drain system.

It is not possible to directly quantify reductions in nutrient loads in urban runoff to inspection and enforcement programs. Accordingly, the water quality benefits that occur as a result of these activities are considered qualitatively as part of the margin of safety associated with implementation of the CNRP.

D.2.4 Construction Site Inspections

MS4 permittees conduct construction site inspections as part of their permit requirements. Reducing sediment and other pollutants in discharges from a construction site is particularly important when reducing nutrient loading to the MS4. This inspection program involves maintaining an inventory database of construction sites 1-acre or larger which are issued a building or grading permits by the permittee. This inventory of construction projects is inspected and reported as part of the Annual Progress Report. Permittees inspect all inventoried constructions sites for compliance with local stormwater ordinances and WQMP requirements. Projects within the San Jacinto watershed are verified to have submitted a Notice of Intent (NOI) with the Regional Board for a Construction General Permit and issued a Waste Discharge Identification (WDID) Number. The inspector also verifies that a Stormwater Pollution Prevention Plan (SWPPP) is on-site and checks that construction BMPs are being implemented. Inspector training is also part of the construction inspection program. Permittee staff inspectors receive annual training in the requirements of the MS4 permits, Construction General Permit, and local stormwater ordinances and enforcement policy.

D.2.5 Street Sweeping and Other Debris Removal Programs

Street sweeping removes debris, which contains nutrients that may potentially be mobilized in urban runoff. The benefits of street sweeping are most closely associated with wet weather runoff which has the greatest capacity to flush unswept and accumulated debris into the storm drain. Table D-2 summarizes the quantity of debris collected by street sweeping programs for each jurisdiction from 2005 through 2010.

The MS4 permittees implement MS4 facility inspection and cleaning programs to satisfy minimum facility maintenance requirements contained in their MS4 permits. The debris that builds up in MS4 facilities has the potential to be a nutrient source that can be mobilized particularly by wet weather flows. The Riverside County permittees annually document the length and percent of pipeline and channel facilities inspected in the Annual Progress Report (Tables D-3 and D-4). Table D-5 summarizes the amount of debris removed annually from MS4 facilities from 2005 to 2010.

Relationships between the volume of debris removed (through street sweeping or MS4 facility cleaning activities) and nutrient load reductions have been established by various studies (CWP, 2008). This information was used to quantify benefits expected from implementation of street sweeping and debris removal programs under the CNRP.

Table D-2. Debris Collected (metric tons) as a Result of Street Sweeping in San Jacinto Watershed, 2005-2010

Jurisdiction	2005	2006	2007	2008	2009	2010
Beaumont[1]	-	-	23	23	23	23
Canyon Lake	-	-	1	2	2	25
Hemet[1]	-	-	1591	909	909	909
Lake Elsinore	-	-	NR	NR	NR	350
Menifee	NA	NA	NA	NA	36	36
Moreno Valley	-	-	1050	1010	706	805
Murrieta	-	-	-	5	5	5
Perris	-	-	588	600	342	495
Riverside[2]	30	30	30	30	28	28
County of Riverside[1]	-	-	797	55	760	540
RCFC&WCD[3]	-	-	-	-	-	-
San Jacinto[1]	-	-	205	189	59	59
Wildomar	NA	NA	NA	NA	25	25

Source: Riverside County Annual Progress Reports, 2005 to 2010

(-): In 2005, 2006, 2007 not all jurisdictions reported this measurement

NA; Wildomar and Menifee incorporated as cities in 2008.

NR; Not reported

[1] Values include debris removal from sweeping performed upstream of Mystic Lake.

[2] City of Riverside data based on reported average removal rate of 0.07 tons/curb mile swept in San Jacinto Watershed portion of City.

[3] RCFC&WCD does not own or maintain streets.

Table D-3. Linear Feet of Pipe and Percent of Pipe Inspected in San Jacinto Watershed, 2005 - 2010

Jurisdiction	Linear Feet or Miles (mi) of Pipe Inspected						Percent Pipe Inspected					
	2005	2006	2007	2008	2009	2010	2005	2006	2007	2008	2009	2010
Beaumont	1,000	1,000	1,000	250	250	250	50	50	50	10	10	10
Canyon Lake	900	900	900	900	900	NR	100	100	100	100	100	100
Hemet	0	0	15,600	0	0	0	0	0	0	0	0	0
Lake Elsinore	ND	ND	ND	4,600	0	0	ND	100	100	100	0	100
Menifee	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	ND	ND
Moreno Valley	100,000	100,000	100,000	100,000	100,000	100,000	100	100	100	100	100	100
Murrieta	0	ND	ND	0	110	0	0	ND	ND	0	0	0
Perris	3,955	402	26,094	28,041	3,013	67,346	4	0.3	17	16	2	36
City of Riverside[1]	0	ND	ND	ND	ND	ND	0	ND	10	10	10	10
County of Riverside[1]	ND	ND	ND	All[2]	6,150	6,150	ND	80	80	100	82	82
RCFC&WCD[1]	ND	ND	All[2]	300 mi	All[2]	All[2]	100	100	100	100	100	100
San Jacinto	12,000	12,000	12,000	9,000	800	1,500	76	76	75	50	5	9
Wildomar	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	ND	ND

[1] Data reflects inspections conducted over entire jurisdiction

[2] All components that can be visually inspected

[3] Data reflects inspections conducted over entire jurisdiction

ND: No data shown

NA: Menifee and Wildomar incorporated as cities in 2008.

Source: Riverside County Annual Progress Reports, 2005 to 2010

Table D-4. Linear Feet of Channel and Percent of Channel Inspected in San Jacinto Watershed, 2005 - 2010

Jurisdiction	Linear Feet or Miles (mi) of Channel Inspected						Percent Channel Inspected					
	2005	2006	2007	2008	2009	2010	2005	2006	2007	2008	2009	2010
Beaumont	2,000	2,000	2,000	2,000	2,000	2,000	100	100	100	100	100	100
Canyon Lake	NA	NA	NA	NA	NA	ND	NA	NA	NA	NA	NA	100
Hemet	15,600	15,600	ND	15,600	15,600	15,600	100	100	100	100	100	100
Lake Elsinore	ND	ND	ND	1,000	1,000	0	ND	100	100	100	100	100
Menifee	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	ND	ND
Moreno Valley	950	950	950	950	950	950	100	100	100	100	100	100
Murrieta	0	ND	ND	7,969	7,969	8,268	0	ND	ND	100	100	100
Perris	16,476	18,181	12,500	10,320	6,557	5,320	78	86	58	48	29	29
City of Riverside[1]	199,000	199,000	ND	ND	ND	ND	100	100	100	100	100	ND
County of Riverside[1]	ND	ND	ND	ND	57,855	60,900	ND	92	92	100	95	100
RCFC&WCD[1]	133 mi	59 mi	160 mi	103 mi	95 mi	230 mi	100	100	100	100	100	100
San Jacinto	16,000	16,000	16,000	19,000	12,000	12,000	94	94	94	100	100	67
Wildomar	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	ND	ND

[1] Data reflect inspections conducted over entire jurisdiction

ND: No data shown

NA: Menifee and Wildomar incorporated as cities in 2008.

Source: Riverside County Annual Progress Reports, 2005 to 2010

Table D-5. Debris (tons) Collected from MS4 Facilities in San Jacinto Watershed, 2005-2010

Jurisdiction	2005	2006	2007	2008	2009	2010
Beaumont	-	-	50	50	50	50
Canyon Lake	-	-	2	1.5	1	1.5
Hemet	-	-	6	5.4	4.9	5
Lake Elsinore	-	-	NR	NR	NR	NR
Menifee	NA	NA	NA	NA	NA	79
Moreno Valley[1]	-	-	1,620	753	408	429
Murrieta[2]	-	-	NR	40	40	42
Perris	-	-	NR	16	113	31
Riverside	-	-	NR	NR	NR	NR
County of Riverside	-	-	15	125	24	25
RCFC&WCD	433	101	263	523	535	260
	11,605	4,331	31,064	5,688	1,840	10,979
San Jacinto	-	-	4	NR	19	19
Wildomar	NA	NA	NA	NA	NR	NR

(-): In 2005 and 2006, not all jurisdictions reported this measurement since Annual Report format did not include this metric.
NA: Wildomar and Menifee incorporated as cities in 2008.
[1]: Reported in cubic feet
[2]: Reported in cubic yards
NR: Not reported
Source: Riverside County Annual Progress Reports, 2005 to 2010

D.2.6 Septic System Management

The Riverside County MS4 permit requires permittees to develop an inventory of septic systems within their jurisdictions to be added to a database managed by County Environmental Health. Poorly operating septic systems can potentially lead to the discharge of pollutants to surface waters. The County Department of Health (DEH) is conducting the following actions in response to MS4 permit requirements for septic systems:

- *Develop a septic system inventory* - Inventories are maintained for any new septic systems which are being installed. Historical data are being captured as resources are available.
- *Evaluate potential water quality impacts* - DEH is considering how to incorporate a GIS/mapping system overlay with current database programs to facilitate septic system evaluations.
- *Conduct public health education* - DEH currently provides both written and electronic information to septic system owners to inform and educate owners to understand proper routine maintenance activities.
- *Conduct inspections & initiate enforcement* - DEH currently responds to all notifications of surfacing sewage in areas within the County served by septic systems. Appropriate enforcement is initiated to ensure any system failures are remedied correctly and promptly.

Additionally, the County of Riverside Environmental Health Division, MS4 Permittees, RCFC&WCD and other stakeholders in the San Jacinto watershed participated in the development of the San Jacinto Septic System Management Plan (SSMP) in 2007. The SSMP includes the following key components and recommendations:

- *Public Education* – Include general public awareness, system owner education, and targeted outreach in critical management zones using a variety of media outlets, workshops, meetings, and direct consultations.
- *Planning* – Include an inventory of the community's wastewater treatment systems, as well as an onsite wastewater plan, to assess onsite wastewater treatment system alternatives.
- *Operation and Maintenance* – Establish maintenance rules, based upon system manufacturers' requirements and qualified septic system experts, and require maintenance contracts with qualified private service providers for systems of a certain size, type, and location. Regular inspection requirements and plumbing frequency recommendations are included in the operation and maintenance component.
- *Reporting and Tracking* – System owners should maintain operation and maintenance records and provide inspection reports to the Regional Board. The management program also recommends developing an online tracking and reporting system where information can be stored and easily retrieved.
- *Site Evaluation, System Design, Installation, Construction* – Site specific observations and characterization shall be performed by a qualified professional when the seasonal high groundwater level is unknown or known to be greater than 10 feet below the ground surface. New and replacement septic tanks installation shall meet California standards.
- *Performance Requirements* – Pollutants of concern should be targeted to reduce bacteria and nutrient loading using performance standards. Supplemental treatment systems will be required for new and replacement septic tanks systems in the critical management zones as well as existing systems that are suspected to be contributing to surface water and groundwater impairment.
- *Monitoring* – Include regular inspections during installation and operation to help identify performance problems quickly.
- *Enforcement and Compliance* – The wastewater management program should be enforced by a regulatory agency such as DEH using appropriate enforcement tools for compliance.

The State Water Resources Control Board (State Board) is in the process of adopting new regulations for septic systems to meet the legal mandate of Assembly Bill (AB) 885[1]. When the new regulations are adopted, the Permittees in the San Jacinto watershed will evaluate the SSMP and revise the SSMP as required.

The conversion of septic systems to a sewer system connection can provide significant water quality benefits. These benefits, in terms of expected nutrient load reductions can be quantified. As a

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[1] AB 885 was passed by the California State Legislature in 2000 requiring the State Board to adopt regulations or standards by January 1, 2004.

consequence, this information was used to quantify benefits expected from septic system conversions that may occur under the CNRP.

D.2.7 Fertilizer Application Management

The MS4 permittees provide Fertilizer Applicator Training on an annual basis. As required by the 2002 MS4 permit, staff responsible for fertilizer application attended at least three training sessions during a permit term. Permittees continue to provide training for public agency staff and contract field operations staff on fertilizer management and model maintenance procedures under the existing MS4 permit. Training includes emphasis on applying fertilizers according to manufacturer specifications, rates, and ratios. Specific fertilizer management practices implemented by MS4 Permittees in the San Jacinto Watershed include:

- *Lake Elsinore* - Staff apply fertilizer to park landscapes at manufacturer specifications, rates, and ratios so as to not over fertilize or under fertilize. Staff ensures excess fertilizer is blown, swept, or removed from the environment.
- *Murrieta* – Staff use organic phosphorus-free fertilizer.
- *Riverside* – Park maintenance staff conduct bi-weekly meetings which include fertilizer application topics. Two City staff are certified Fertilizer/Pesticide Applicators.
- *San Jacinto* – The city requires contract vendors to apply fertilizer three times per year and specifies that the vendor notify City staff prior to each application.

It is not possible to directly quantify reductions in nutrient loads in urban runoff to fertilizer application and training activities. Accordingly, the water quality benefits that occur as a result of these activities are considered qualitatively as part of the margin of safety associated with implementation of the CNRP.

D.3 Structural BMPs

The MS4 Permittees have been implementing structural BMPs in the watershed to fulfill new development and significant redevelopment requirements incorporated into the 2002 MS4 permit adopted for the Santa Ana Region within Riverside County and as required by Watershed-wide Waste Discharge Requirements for Discharges of Stormwater runoff Associated with New Developments in the San Jacinto Watershed (Regional Board Order 01-34). These structural BMP requirements have been implemented through the development of Water Quality Management Plans for development projects. Table D-6 summarizes the number of projects and number of acres of runoff impacted by the implementation of WQMPs since January 1, 2005, shortly after adoption of the Nutrient TMDLs.

Table D-6. Summary of Structural BMPs Implemented as Required by Implementation of WQMP Requirements for New Development or Significant Redevelopment Activities

Jurisdiction	No. of Projects	Total Acres	Description
Beaumont			
Canyon Lake	-	-	
Hemet	22	108	Infiltration basins, extended detention, bioretention basins, grass swales, underground chamber
Lake Elsinore	38	2,710	Water quality basins, swales, bio-retention
Menifee	12	75	Extended detention basins
Moreno Valley	20	1,220	Extended detention basins, vegetated swales, media filter
Murrieta	2	34	Infiltration basin, swale
Perris	73	2,233	Extended detention, infiltration basins, bioswales, and media filters
Riverside	-	511	
Riverside County	6	25	Extended detention basins. County did not have a tracking mechanism for San Jacinto Construction Permit SWPPP projects that deployed BMPs. As they could not be accounted for, they are not tracked here. The numbers here represent only projects subject to WQMP requirements that have been constructed within the unincorporated County. These numbers also do not include additional WQMP projects originally constructed within the County that have since been incorporated into cities.
San Jacinto			
Wildomar	-	-	
Total	**176**	**6,916**	

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Attachment E
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Tables

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Attachment E
CNRP Implementation Plan

E.1 Introduction

As noted in Section 2.4, the MS4 permit requires that the CNRP include a detailed schedule includes the following:

- Discrete milestones, decision points and alternative analyses necessary to assess satisfactory progress toward meeting the urban WLAs for nutrient by December 31, 2020.
- Agency or agencies are responsible for meeting each milestone.
- Specific metric(s) that demonstrate the effectiveness of the CNRP and acceptable progress toward meeting the urban WLAs for nutrient by December 31, 2020

Section 2.4 provided an illustration of the key CNRP elements in a timeline. In this attachment, Table E-1 provides the detailed information required above for each CNRP task, specifically:

- *CNRP Activity* – Programmatic area to be implemented;
- *Milestones* – Discrete actions associated with the completion of each CNRP activity;
- *Metrics* – Specific outcomes to demonstrate completion of each milestone;
- *Lead Agency* – Assignment of the activity to the appropriate jurisdiction or group of stakeholders; and
- *Completion Date* – Completion dates for the CNRP activities.

E.2 CNRP Activities

The following sections provide a brief summary of the activities that will be completed under each key CNRP element.

E.2.1 Watershed-based BMPs

Three BMPs will be evaluated by the permittees to determine if modifications or enhancements can and need to be made that will provide additional reduction of nutrient sources within their jurisdictions:

- Ordinances
- Street Sweeping
- Debris Removal

The implementation schedule includes milestones for the evaluation of these BMPs and, if appropriate, completion of program modifications.

Two BMPs will continue to be implemented as currently designed. Public education and outreach activities (PEO) that target nutrients are already routinely implemented. The MS4 program will continue to regularly evaluate these activities and update PEO programs as needed. Septic system management will continue as described by the approved San Jacinto Onsite Wastewater Management Program.

Future development in the watershed is subject to recently revised WQMP requirements that require implementation of LID-based BMPs. The revised WQMP will be fully implemented April 22, 2013, likely prior to the expected CNRP approval date.

E.2.2 In-lake Remediation Projects

Lake Elsinore

The Lake Elsinore aeration system, incorporated into the CNRP, is already being implemented. During CNRP implementation the MS4 permittees will support the continued operation of this system as needed to comply with urban WLAs. However, as noted in Section 2.2.2., the permittees will continue to evaluate alternative compliance approaches including use of chemical additives such as alum. If it is determined that an alternative approach is more cost effective for achieving compliance with the urban WLAs and septic LAs, the Permittees will recommend revision to the CNRP.

Canyon Lake

The Taskforce has completed detailed evaluations of aeration, oxygenation, and chemical addition (Anderson, 2008; CDM, 2011; Anderson, 2012b; Anderson, 2012c). Based on these evaluations, the Taskforce has determined that chemical addition, using aluminum sulfate (alum), is the most effective in-lake nutrient control strategy to achieve interim numeric targets for the response variables, chlorophyll-a and DO. Appendix C provides the basis for this determination. Beginning in September 2013, assuming CEQA compliance is complete, alum application will be performed according to the schedule shown in Table 3-19. After the fifth alum application in September of 2015, the MS4 Permittees will evaluate water quality data in the lake, and determine whether response targets are achieved or if modification to the alum application plan or potential supplemental BMPs may be needed to achieve response targets for chlorophyll-a and DO (see Table E-1 in Attachment E for detailed implementation schedule).

In 2016, the TMDL will be reopened to revise the final numeric target for DO to incorporate controllability by means of an allowable exceedence frequency representative of a pre-development condition in the watershed. The 2012 DYRESM-CAEDYM simulations of lake water quality expected for a pre-development level of watershed nutrient loads will be used as the basis for determining the uncontrollable frequency of exceeding a final DO target of at least 5 mg/L in the hypolimnion. A cumulative frequency plot of average daily DO data from the two year period of alum applications (Sep 2013 through Sep 2015) will be compared to the pre-development cumulative frequency to determine whether sufficient improvement to DO was achieved with the alum applications. If not, the Permittees will consider a supplemental in-lake project for DO, such as aeration or oxygenation.

E.2.3 Monitoring Program

Watershed-based monitoring will continue at current levels through fiscal year 2014-2015. The Permittees propose to eliminate existing in-lake monitoring programs through the same period to ensure that resources are dedicated to implementation of projects contained in the CNRP. By December 31, 2014, the permittees will propose a revised comprehensive watershed and in-lake monitoring program for implementation beginning in fiscal year 2015-2016. The level of effort associated with this revised program will be sufficient to provide data to assess compliance with the 2015 interim and 2020 final TMDL compliance requirements. These compliance assessments will provide the basis for determining whether the CNRP requires revision to ensure compliance with TMDL requirements. Annual monitoring reports will be submitted to the Regional Board by November 30th of each year, at the same time that the MS4 Annual Report is submitted to the Regional Board.

E.2.4 Special Studies (optional)

The CNRP identifies several special studies that may be completed during implementation. Their primary purpose is to develop new data or information that could provide the basis for revisions to the Nutrient TMDLs or CNRP. Two studies listed in Table E-1 (land use updates and TMDL model update) may be implemented by the MS4 Permittees, but only if it is determined that the expenditure of resources on these efforts would yield appropriate outcomes. For that reason, Table E-1 notes that these tasks are optional and only lists general milestones and metrics. If the studies were to be implemented, the efforts would be coordinated with other stakeholders to the extent necessary. Currently, given the TMDL triennial review schedule, which provides periodic opportunity to revise the TMDL, these studies would be completed in a timely manner to inform the triennial review process.

E.2.5 Adaptive Implementation

This CNRP element covers activities associate with continued participation in the Task Force, the development project specific PTPs or functionally equivalent agreements, and the need, where appropriate, for revisions to the CNRP or Nutrient TMDLs. The need for modification of the CNRP will be determined by the findings of any special studies (if implemented) and the results of ongoing monitoring efforts which provide the basis for assessments of compliance with TMDL requirements. This assessment will include completion of a trend analysis for the response targets and nutrient levels in Lake Elsinore and Canyon Lake by November 30, 2018. This analysis will be included in the fiscal year 2018-2019 MS4 Annual Report. Based on the outcome of this analysis, the permittees may make recommendations for additional BMPs and a schedule for deployment of those BMPs for incorporation into a revised CNRP by June 30, 2019.

Adaptive implementation also includes a provision for providing support to the TMDL revision process. Recommendations for revisions to the TMDL would be made by the Permittees working in collaboration with other TMDL stakeholders. Any recommendations made would be based on the findings of special studies or the data obtained from the monitoring program. The schedule for TMDL revisions is based on the TMDL review schedule that anticipates opportunity for TMDL revisions every three years.

Table E-1. CNRP Implementation Plan

CNRP Activity	CNRP Element	Milestones	Metrics	Lead	Estimated Complete by
Watershed-based BMPs	Ordinances Development	Evaluate need to revise existing or establish new ordinances to reduce sources of nutrients in the watershed	Complete ordinance evaluation	Permittees	March 31, 2014
			Develop revised or new ordinances (where needed)	Permittees	December 31,2014
	Street Sweeping & Debris Removal	Street Sweeping & Debris Removal	Evaluate existing street sweeping and debris removal programs to identify opportunities to enhance program	Permittees	March 31, 2014
			Implement program enhancements, where identified, and as approved in local jurisdiction	Permittees	December 31, 2014
			Annual reporting of regular street sweeping and debris removal outcomes in Annual Report, with emphasis on TMDL benefits	Permittees/MS4 Program	November 30, each year
	Inspection & Enforcement	Continued implementation of inspection and enforcement program	Update inspection and enforcement program if needed based on outcome of ordinance evaluation	Permittees	March 31, 2015
			Annual reporting of regular inspection and enforcement activities in Annual Report	Permittees/MS4 Program	November 30, each year
	Septic System Management	Continued implementation of Septic System Management Plan for the watershed; modify implementation as needed to comply with State OWTS Policy	Annual reporting of septic system management activities in Annual Report,	Permittees	November 30, each year
	Public Education & Outreach	Continued implementation of PEO program	As part of Annual Report preparation evaluate PEO program to determine need to modify or expand PEO activities that target nutrient sources	Permittees/MS4 Program	November 30, each year
			Update PEO materials, as needed; implement PEO program	Permittees/MS4 Program	Annually, as needed
	WQMP Implementation	Implement approved LID-based WQMP following Regional Board approval	Prepare final WQMP, obtain Regional Board approval, and implement in watershed	Permittees/MS4 Program	Full WQMP Implementation-April 22, 2013

Table E-1. CNRP Implementation Plan

CNRP Activity	CNRP Element	Milestones	Metrics	Lead	Estimated Complete by
In-Lake Remediation Projects	Lake Elsinore	Support implementation of existing lake aeration system	Establish necessary agreements among aeration system participants	MS4 Program in collaboration with stakeholders	June 30, 2013
	Canyon Lake	Conduct tests to evaluate potential for chronic aluminum toxicity with planned doses of alum	Toxicity test results to support CEQA initial study	MS4 Program in collaboration with stakeholders	March 15, 2013
		Complete CEQA process	CEQA initial study and approval of alum addition plan	MS4 Program in collaboration with stakeholders	July 31, 2013
		Implement process to obtain all permits and approvals	Secure permits and approvals to add alum from barge at surface	MS4 Program in collaboration with stakeholders	September 30, 2013
		Implement planned alum additions	Completion of planned alum additions to surface of Main Body and East Bay using barge	MS4 Program in collaboration with stakeholders	September , 2013, February, 2014, September 2014, February, 2015, September, 2015
		TMDL reopener for DO response target	Revision of response target that takes into account controllability considerations	MS4 Program in collaboration with stakeholders	June 30, 2016
		Support implementation of long-term in-lake nutrient management BMPs	If needed, establish additional watershed or in-lake BMPs to meet final response targets (e.g. regular alum additions, aeration, HOS, etc.)	MS4 Program in collaboration with stakeholders	December 31, 2020
Monitoring Program	In-Lake Monitoring	Implement alum treatment effectiveness monitoring	Develop and begin implementation of a plan for effectiveness monitoring to obtain sufficient data to evaluate performance of alum treatment in Canyon Lake.	MS4 Program in collaboration with stakeholders	June, 2014
		Prepare revised comprehensive monitoring program	Submit revised comprehensive monitoring program to the Regional Board for approval	MS4 Program in collaboration with stakeholders	December 31, 2014
		Implement Regional Board-approved revised comprehensive monitoring program	Completion of annual monitoring as required by revised program	MS4 Program in collaboration with stakeholders	December 31, 2020

Table E-1. CNRP Implementation Plan

CNRP Activity	CNRP Element	Milestones	Metrics	Lead	Estimated Complete by
	Watershed-based Monitoring	Continue implementation of Phase I watershed monitoring program	Completion of annual monitoring as required by current approved monitoring program	MS4 Program in collaboration with stakeholders	June 30, 2015
		Prepare revised comprehensive monitoring program	Submit revised comprehensive monitoring program to the Regional Board for approval	MS4 Program in collaboration with stakeholders	December 31, 2014
		Implement Regional Board-approved revised comprehensive monitoring program	Completion of annual monitoring as required by revised program	MS4 Program in collaboration with stakeholders	December 31, 2020
	Annual Reports	Complete annual reports to assess effectiveness of CNRP	Submittal of annual reports to Regional Board	MS4 Program in collaboration with stakeholders	November 30, annually
	Interim Compliance Assessment	Demonstrate compliance with interim TMDL requirements	Submittal of assessment of compliance with interim TMDL requirements	MS4 Program in collaboration with stakeholders	June 30, 2016
	Final Compliance Assessment	Demonstrate compliance with WLAs	Submittal of assessment of expected compliance with final TMDL requirements including any recommended supplemental actions.	MS4 Program in collaboration with stakeholders	December 31, 2020
Special Studies (Optional)	Land Use Updates	Update watershed urban land use based on 2010 data	Submit land use revision to the Regional Board	MS4 Program in collaboration with stakeholders	June 30, 2018
	TMDL Model Update	Revise/update TMDL models for Canyon Lake/ Lake Elsinore based on new data (e.g., land use, water quality)	Submit TMDL models to the Regional Board	MS4 Program in collaboration with stakeholders	December 31, 2018

Table E-1. CNRP Implementation Plan

CNRP Activity	CNRP Element	Milestones	Metrics	Lead	Estimated Complete by
Adaptive Implementation	Task Force	Participate in Task Force process	Regular attendance at Task Force meetings	MS4 Program in collaboration with stakeholders	Ongoing
	CNRP Revisions	Review progress towards achieving TMDL requirements based on compliance assessments; modify CNRP as needed	Prepare compliance assessment; if needed, submit revised CNRP to the Regional Board	MS4 Program/Permittees	November 30, 2016
		Review progress towards achieving final TMDL requirements based on compliance assessments; modify CNRP as needed	Prepare compliance assessment; if needed, submit revised CNRP to the Regional Board	MS4 Program/Permittees	June 30, 2020
	TMDL Revision	Based on degree of Regional Board support, prepare materials to support revision to the TMDL, coordinate with Triennial Review process, if revision is appropriate and feasible.	Submit recommendations and supporting material for revisions to the TMDL to the Regional Board	MS4 Program in collaboration with stakeholders	Prior to potential triennial review dates in 2015 and 2019

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Attachment F
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